U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 156.

A. C. TRUE, Director.

STUDIES

ON THE

DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD AND OF MACARONI

AT THE

UNIVERSITY OF MINNESOTA

1903-1905.

BY

HARRY SNYDER, B. S.,

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WASHINGTON:

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1905.

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[Continued on third page of cover.]

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 30, 1905.

Sir: I have the honor to transmit herewith and recommend for publication as a bulletin of this Office, a report of investigations on the digestibility and nutritive value of bread, and of macaroni and a breakfast food made from American-grown durum wheat, carried on at the University of Minnesota in 1903–1905 by Harry Snyder, professor of chemistry in the State University and chemist of the Agricultural Experiment Station. The studies are a continuation of the investigations on the nutritive value of cereal products conducted at the University of Minnesota by Professor Snyder and at the Maine Agricultural Experiment Station by Prof. Charles D. Woods, and were undertaken under the same general conditions as the other nutrition investigations on the food of man conducted under the auspices of this Office.

Thanks are due to the Oklahoma and Oregon experiment stations for samples of hard and soft winter wheats, and to the North Dakota Experiment Station and the North Dakota Substation for samples of durum wheat; also to the Minnesota Macaroni Company, of St. Paul, for making the macaroni from specially ground wheat.

The results of the investigations with bread of different sorts are in accord with those obtained in former studies, and apparently warrant the belief that it may be laid down as a general rule that bread from fine patent flours is more thoroughly digestible and so has a higher nutritive value than that from the coarse flours ground from the same lots of wheat, although pound for pound it contains somewhat less protein and mineral matter. Furthermore, the investigations confirm the belief that all flours are quite thoroughly digested, and furnish additional proof of the high nutritive value of flour of all grades. The experiments with macaroni indicate that this product is very thoroughly digested, being very similar in this respect to patent flour bread, and that the American product made from native durum wheat is equal in digestibility and food value to European goods.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD.

INTRODUCTION.

Some years ago it was estimated that the amount of wheat consumed annually in the United States was 4.5 bushels per capita. This would be equivalent to about 200 pounds of flour. Later estimates place the quantity at 6.23 bushels, which would be equal to 277 pounds of flour. Because of its importance no article of food has received more attention from investigators during recent years than flour. In 1897 an extended series of experiments was undertaken at the Maine and the Minnesota experiment stations to determine the digestibility and nutritive value of different grades of flour prepared from the same and from different kinds of wheat. Preceding bulletins of this Office contain accounts of the results of investigations at the Maine[a] and Minnesota[b] stations for 1897 to 1902; similar work at the latter station for 1903–4 is reported herein.

The general plan of these investigations has been to prepare the three common types of flour—Graham, entire-wheat, and standard patent—from the same lot of wheat, and then determine their comparative digestibility and nutritive value by experiments with bread made from the flours. As stated in a former report,[c] Graham flour is unbolted ground wheat; entire-wheat flour contains all of the wheat kernel with the exception of a portion of the bran which is removed with a coarse screen, while the standard patent, or, as hereafter designated, straight-grade, flour contains neither the bran nor the germ, but is fine white flour which has passed through a No. 14 bolting cloth with 193,211 meshes per square inch.

The necessity for confining the comparisons to samples prepared from the same lot of wheat has also been pointed out.[d] It is not possible to compare accurately the nutritive values of the various types

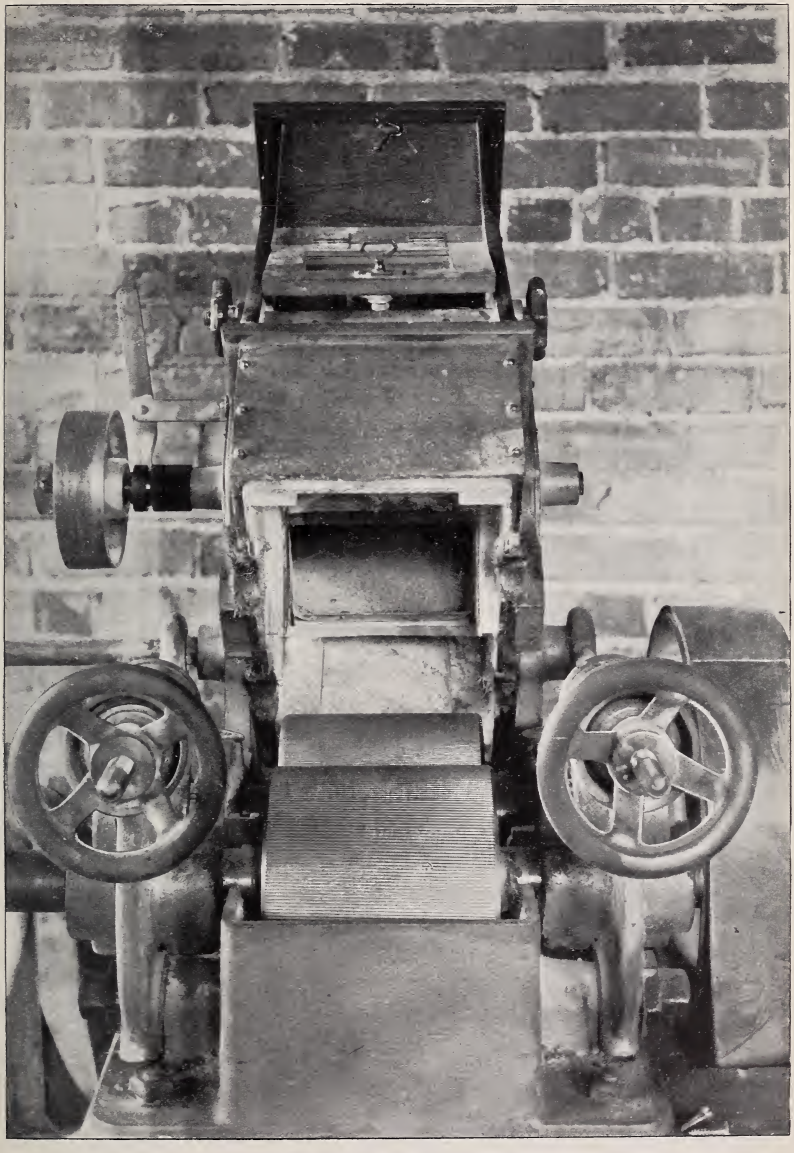
[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 85, 143.
[b] U. S. Dept. Agr., Office of Experiment Stations Buls. 67, 101, 126.
[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 8.
[d] U. S. Dept. Agr., Office of Experiment Stations Buls. 101, p. 6; 126, p. 8.

of flour when each is prepared from a different lot of wheat, because of the wide variations in composition of different kinds of wheats.

The investigations previously reported have shown that while the coarser flours are somewhat superior as regards the total protein and ash present they are inferior as regards digestibility, and that when these facts are considered together the advantage from the standpoint of nutritive value is with the finer flour. The earlier experiments were made with wheats from widely different localities, including Minnesota northern-grown hard spring wheat, Michigan soft winter wheat, Indiana soft winter wheat, Oklahoma hard winter wheat, and Oregon soft winter wheat, and it seemed important to determine whether similar differences in the composition and digestibility of bread from the different kinds of flour would be noted with flours ground from other types of wheat and whether it was not fair to say that the differences observed were characteristic of all wheats, provided flours were ground from the same sample of grain. The wheats selected for the present investigation were Oklahoma hard winter wheat and Oregon soft winter wheat secured from the Oklahoma and Oregon experiment stations, respectively. These are described in detail beyond (p. 12). Portions of each lot were milled into straight-grade, entire-wheat, and Graham flour, as described below, and the digestibility and nutritive value of each determined from digestion experiments with healthy young men. Furthermore, in order to ascertain the influence on completeness of digestion of the bran and the germ, generally removed in the milling of white flour, samples of bran and of germ were prepared and added to successive samples of Oklahoma straight-grade flour in about the same amounts as were removed during the milling process, and the digestibility and nutritive value of bread from these products likewise determined with the same subjects.

MILLING THE SAMPLES OF WHEAT.

The wheats used in the experiments previously reported were milled in one of the large mills of Minneapolis and in smaller mills in Michigan and Indiana, where somewhat different systems of milling were employed. Although the products of the different systems were of the same general character, samples prepared under uniform conditions afford data for more definite and positive comparisons. Accordingly, in the present investigation, a mill especially devised for experimental purposes, and procured mainly for these experiments, was used. The mill is provided with four sets of rollers, including both corrugated and smooth rollers (illustrated in Plate I), and has the essential features of a patent roller-process mill such as is used in large milling plants. It is supplied with a bolting and sifting attachment and is, in fact, a roller mill in miniature. By its use it is possible



CORRUGATED ROLLERS OF MILL.

to prepare straight-grade, Graham, or entire-wheat flours from a small sample of wheat.

The Oregon and Oklahoma wheats were milled under the supervision of an experienced miller, and the flour was subjected to the inspection of the chief flour inspector of one of the large milling companies of Minneapolis.

The milling was carried on in the usual way.[a] The screened wheat was first passed through corrugated rollers to split the wheat kernel and flatten the germ. As in ordinary milling it was necessary, in grinding the samples, to dampen the wheat so as to prevent the bran from breaking up into fine pieces and contaminating the straight-grade flour. After passing through the second break, small amounts of break flour[b] and granular middlings were separated by means of a fine screen and bolting cloths. The stock was removed from the second break and the tailings passed on to the third break, which resulted in the liberation and reduction of additional quantities of flour and middlings, and then on to the fourth break. With each reduction the rollers were set a little closer. The granular middlings and stock were passed through the smooth rollers three times and finally all brought together. All of the straight-grade flour was passed through a No. 14 bolting cloth (illustrated in Plate II) and thoroughly mixed, the bran, shorts, germ, and other offals being removed at the different boltings from the several breaks.

This process of milling is known as the gradual reduction process. Break flours are first produced and then the granular middlings are liberated from the tailings and bran and reduced. The second break flour is obtained largely from the interior or more floury portions of the wheat kernel and is more starchy in character than later break flours. The third break flour contains a higher percentage of gluten and other proteids than the second break flour. The middlings from the second break are more nitrogenous in character than those from the later breaks. During the process of milling the break flours become more nitrogenous, while the middlings become more starchy in character. The different break flours and middlings, with the exception of a small amount which is separated as second clear or low-grade flour, are finally united, thoroughly mixed and bolted, forming straight-grade flour.

In the milling of these wheats about 70 per cent of the entire wheat was obtained as straight-grade flour. In the large mills, where the

[a] For a somewhat more detailed account of the milling process, see Minnesota Station Bul. 85, pp. 189, 190.

[b] In each reduction or "break" the "break flour" is the portion passing through the screen and bolting cloths. The "granular middlings" pass through the screen but not the final bolting cloth, and are afterwards reduced to flour. The portion not passing through the screen is known as the "tailings," and passes on to the next "break."

offals are subjected to more exhaustive milling, about 72 per cent of straight-grade flour is secured. The milling of the samples in the laboratory under chemical control has proven unusually satisfactory, as it has enabled the different wheats to be milled and the flours prepared on a uniform basis, thus rendering the results more valuable.

DESCRIPTION OF SAMPLES OF WHEATS AND FLOURS.

A description of the wheats used in this investigation, together with the different grades of flour and milling products made from them, is here given:

No. 269. Oregon white winter wheat weighing 60 pounds per bushel, grown at the Oregon Experiment Station, Corvallis, Oreg. (See Plate III.) Director J. Withycombe, of the Oregon Station, states that this variety of wheat was introduced into western Oregon about sixty years ago by the Hudson Bay Company. It is a wheat with large white plump starchy kernels.

No. 271. Graham flour prepared from Oregon wheat, No. 269. Graham flour is practically wheat meal and consists of the entire wheat kernel, including bran, germ, and offal. As no sieves or bolting cloths are used in its preparation, there are many coarse unpulverized particles present in the product.

No. 272. Entire-wheat flour from Oregon wheat, No. 269. Entire-wheat flour is prepared by removing the larger portion of the coarse bran, while the fine bran, or shorts, and germ are retained in the flour. This was done by the use of coarse wire screens. The flour was subjected to two breaks on the coarse and two on the smooth rollers. Entire-wheat flour is of finer granulation than Graham, but much coarser than straight-grade flour.

No. 273. Straight-grade flour from Oregon wheat, No. 269. The grain was run through three coarse rollers three times, the flour being taken out at each break. The middlings were passed through three smooth rollers three times and the flour removed each time. The bran was fairly free from flour. About 70 per cent of the wheat was recovered as straight-grade flour.

No. 270. Hard winter Weissenburg wheat weighing 62 pounds per bushel, grown at the Oklahoma Experiment Station, Stillwater, Okla. (see Plate III). Director J. Fields states that the original seed was obtained through W. T. Swingle, of the U. S. Department of Agriculture, and was designated No. 3821. This sample is characteristic of the winter wheat grown in that locality, and in yield compares very favorably with other leading varieties. The kernels were of medium size, amber color, and glutinous character.

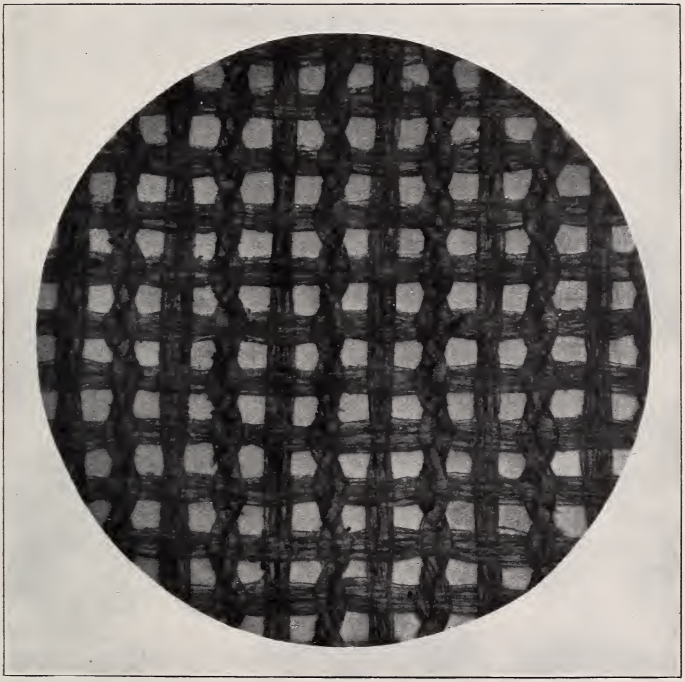
No. 274. Graham flour from Oklahoma wheat, No. 270. This was prepared in the same way as No. 271.

No. 275. Entire-wheat flour from Oklahoma wheat, No. 270. This was prepared in a manner similar to No. 272, and 86 per cent of the wheat was recovered as entire-wheat flour.

No. 276. Straight-grade flour from Oklahoma wheat, No. 270. This was prepared in the same way as No. 273. About 70 per cent of straight-grade flour was recovered.

No. 413. Bran from Oklahoma wheat, No. 270. Bran consists of the coarsely ground episperm or outer covering of the wheat kernel. The sample was ground in a burr mill and then in a Maerker mill.

No. 414. Germ from Oklahoma wheat, No. 270. The germ is the undeveloped plumule. In the process of straight-grade flour making it is excluded, because, as it is fermentable in character, it impairs the keeping qualities of the flour and pro-



BOLTING CLOTH NO. 14 (MAGNIFIED 48 DIAMETERS) THROUGH WHICH THE STRAIGHT-GRADE FLOUR WAS PASSED.

FIG. 1.—OREGON AND OKLAHOMA WHEATS.

Rows 1 and 2, Oregon white winter wheat from sample No. 269, containing 9.12 per cent protein. Rows 3 and 4, Oklahoma winter wheat from sample No. 270, containing 16.82 per cent protein.

FIG. 2.—OREGON AND OKLAHOMA WHEATS.

Rows 1 and 2, sections of Oregon white winter wheat. Rows 3 and 4, sections of Oklahoma winter wheat.

duces an inferior quality of bread. The sample was ground in the same way as the bran.

No. 415. Bran flour. The sample was prepared by adding 14 per cent of finely ground bran (No. 413) to the straight-grade Oklahoma flour (No. 276).

No. 416. Germ flour. The sample was prepared by mixing 93 per cent of straight-grade Oklahoma flour (No. 276) with 7 per cent of finely ground germ (No. 414).

COMPOSITION OF SAMPLES OF WHEATS AND FLOURS.

Complete proximate analyses of all of the wheat and flour samples were made according to the methods recommended by the Association of Official Agricultural Chemists.[a] The protein content was calculated by the use of two factors, namely, 5.7 and 6.25. Investigations have shown that the principal wheat proteids contain about 17.6 per cent nitrogen instead of 16 per cent, the value upon which the factor 6.25 is based, which is commonly used for calculating protein from nitrogen. The use of the factor 5.7 gives lower values for the protein, but the results undoubtedly represent more nearly the actual amount in the wheat than that obtained by the factor 6.25. However, for the sake of comparison with investigations previously reported in which the factor 6.25 was used, the protein is also computed by the use of this factor. The carbohydrates determined by difference are also estimated on the basis of protein as computed by both factors. The heat of combustion was determined by combustion in a Berthelot-Atwater bomb calorimeter, as described in a former publication.[b] In the case of the milk samples weighed blocks of cellulose were employed to absorb the liquid, according to the method described in a former report.[c] The calculated heats of combustion of the wheat and flour samples were obtained by the use of the following factors: Protein, 5.9; fat, 9.3; and carbohydrates, 4.2 calories per gram. Earlier investigations have shown that when the principal nutrients of wheat flour were separated, purified, and burned in the calorimeter they yielded the following values per gram: Wheat starch 4.190 calories, wheat fat 9.282 calories, gliadin 5.924 calories, and glutenin 5.879[d] calories. The calculated and determined heats of combustion of the flour samples agree quite closely, though the agreement is not perfect because of the presence of cellulose and other substances which have a factor for heat of combustion different from that used in the calculation.

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[a] U. S. Dept. Agr., Division of Chemistry Bul. 46, revised edition.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 10.

[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 126, p. 9.

[d] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 13.

TABLE 1.—*Composition and heat of combustion of wheats and flours.*

Sample number.	Kind of material.	Water.	Protein.		Fat.	Carbohydrates when protein is estimated as—		Ash.	Heat of combustion per gram.	
			(N × 6.25)	(N × 5.7).		N × 6.25.	N × 5.7.		Calculated.	Determined.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*	*Calories.*
269	Oregon wheat...	8.99	9.12	8.32	1.83	78.30	79.10	1.76	3.997	4.008
271	Graham flour from No. 269...	8.15	8.97	8.18	1.68	79.48	80.27	1.72	4.023	3.990
272	Entire-wheat flour from No. 269.....	8.66	8.25	7.52	1.67	80.35	81.08	1.07	4.016	3.900
273	Straight-grade flour from No. 269.....	8.94	7.55	6.90	1.25	81.82	82.47	.44	3.998	3.880
270	Oklahoma wheat.....	8.65	16.82	15.33	1.83	71.38	72.87	1.32	4.160	4.110
274	Graham flour from No. 270...	7.73	16.81	15.33	1.79	72.35	73.83	1.32	4.196	4.178
275	Entire-wheat flour from No. 270.....	7.46	16.63	15.16	1.64	73.05	74.52	1.22	4.201	4.159
276	Straight-grade flour from No. 270.....	9.93	15.06	13.74	.92	73.57	74.89	.52	4.065	4.040
413	Bran.....	9.91	16.39	14.93	4.50	62.79	64.25	6.41	4.022	4.103
414	Germ.....	8.73	29.88	27.24	11.23	45.45	48.09	4.71	4.716	4.597
415	Bran flour.....	9.69	15.35	13.96	1.48	72.23	73.62	1.25	4.077	3.876
416	Germ flour.....	9.63	16.30	14.87	1.66	71.54	72.97	.87	4.124	3.962

Table 1 illustrates the fact that different wheats and different types of flour vary widely in composition. Thus, straight-grade flour (No. 276) prepared from Oklahoma wheat contained a much larger amount of protein than Graham flour (No. 271) prepared from Oregon wheat. This emphasizes the importance, previously pointed out, of preparing the different kinds of flour for investigations of this nature from the same lot of wheat. Otherwise, if a straight-grade flour milled from one lot of wheat were compared with an entire-wheat flour milled from another and entirely different lot of wheat, the straight-grade flour might contain either more or less starch or protein than the Graham flour, according to the character of the wheats from which they were prepared. From the data in Table 1 it will be observed, however, that for both the Oregon and Oklahoma wheats the Graham flour contained more protein and fat and less carbohydrates than the entire-wheat flour, which in turn contained more protein and fat and less carbohydrates than the straight-grade flour.

It will be observed from this table that the Oregon and Oklahoma wheats and flours were decidedly unlike in character. The Oregon wheat (sample No. 269) was starchy and characterized by a low protein content, while the Oklahoma wheat (No. 270) was glutinous in character and contained a high percentage of protein. The straight-grade flour from the Oregon wheat contained 1.47 per cent of total nitrogen, 70.1 per cent of the proteids being in the form of gliadin soluble in 70 per cent alcohol, while the straight-grade flour from the Oklahoma wheat contained 2.41 per cent total nitrogen, of which 59.75 per cent was in the form of gliadin.

As pointed out in a former report[a] the ash content varies so regularly in different grades of milling products that it is possible to determine the grade of flour by determining the amount of ash which it contains. In these samples the ash content of the flour sample agrees closely with that known to be present in standard grades of straight-grade, entire-wheat, and Graham flour.

COMPOSITION OF SAMPLES OF FOOD MATERIALS.

The table below gives the data regarding the composition of the foods consumed in the digestion experiments. The values given in each case are the result of actual analysis, except that the percentage of fat in the dry matter of the flour is used as a basis in the calculations for the fat content of bread. The results thus obtained are known to be more accurate than those secured from the analysis of the bread, because during the process of bread making the fat of the flour is in part rendered insoluble.[b]

A sample of 100 grams from each loaf of bread used was dried and a composite sample for analysis was then taken proportional to the weight of the loaves and the quantity consumed. This has been found to be the most satisfactory method of sampling and preparing bread for analysis. A composite sample of milk was made for each of the digestion trials by reserving 25 cubic centimeters of the mixed milk taken at each meal, 100 milligrams of potassium bichromate being used as a preservative.

TABLE 2.—*Composition of bread and milk used in digestion experiments with Oregon and Oklahoma wheat breads.*

Sample No.	Kind of material.	Water.	Protein ($N \times 6.25$).[c]	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
	Bread made from:	*Per ct.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
277	Oregon entire-wheat flour	39.95	5.70	[d]1.09	52.39	0.87	2.566
294	Oregon straight-grade flour	34.95	5.41	[d].89	57.85	.90	2.765
311	Oregon Graham flour	38.55	6.11	[d]1.12	52.68	1.54	2.562
328	Oklahoma straight-grade flour	37.65	10.13	[d].64	51.14	.44	2.783
345	Oklahoma entire-wheat flour	41.31	10.60	[d]1.04	46.11	.94	2.714
362	Oklahoma Graham flour	42.20	10.65	[d]1.12	44.58	1.45	2.516
379	Straight-grade flour with 14% bran	43.20	9.50	[d].84	45.55	.91	2.499
396	Straight-grade flour with 7% germ	38.00	11.07	[d]1.13	49.12	.68	2.793
278	Milk, composite sample	88.34	3.62	3.58	3.77	.69	.613
295	do	87.28	2.96	4.46	4.46	.84	.765
312	do	87.74	1.77	4.36	5.33	.80	.681
329	do	87.92	2.90	3.69	4.66	.83	.643
346	do	87.53	2.87	4.30	4.60	.70	.709
363	do	86.88	2.94	5.86	3.45	.87	.690
380	do	86.95	3.49	4.93	3.60	[e]1.03	.800
397	do	86.83	3.05	4.35	5.02	.75	.750

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 9.
[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 45.
[c] For explanation of the use of the factor 6.25 for calculation of protein in bread see p. 18.
[d] Fat content of dry matter of flour.
[e] High ash due to abnormal amount of preservative used in composite sample.

COMPOSITION OF FECES AND URINE.

The feces for the experimental period were collected and analyzed by the usual methods. The separations of the feces at the beginning and end of each period were effected by means of charcoal in gelatin capsules as a marker.[a] The data regarding the composition of the feces are here tabulated.

TABLE 3.—*Composition of dry matter of feces from digestion experiments with Oregon and Oklahoma wheat bread.*

Sample No	Whence obtained.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
291	Experiment No. 469	25.90	12.78	38.40	22.92	4.500
292	Experiment No. 470	24.05	9.27	45.80	20.88	4.457
293	Experiment No. 471	25.26	11.26	41.75	21.73	4.500
308	Experiment No. 472	28.95	12.64	31.59	31.82	4.619
309	Experiment No. 473	25.37	11.32	27.89	35.42	3.960
310	Experiment No. 474	29.22	9.97	33.36	27.45	4.229
325	Experiment No. 475	22.41	11.21	48.53	17.85	4.578
326	Experiment No. 476	21.57	10.48	48.44	19.51	4.295
327	Experiment No. 477	32.52	11.87	36.52	19.09	4.438
342	Experiment No. 478	24.88	9.32	39.12	26.68	4.880
343	Experiment No. 479	28.97	7.71	31.98	31.34	4.124
344	Experiment No. 480	29.17	13.82	29.80	27.21	4.261
359	Experiment No. 481	27.77	6.69	49.55	15.99	4.804
360	Experiment No. 482	24.36	7.43	50.31	17.90	4.447
361	Experiment No. 483	23.87	10.37	45.20	20.56	4.510
376	Experiment No. 484	22.85	10.13	49.98	17.09	4.726
377	Experiment No. 485	22.46	8.51	52.97	16.06	3.282
378	Experiment No. 486	23.54	11.53	46.60	18.33	4.452
393	Experiment No. 487	23.90	13.33	41.05	21.72	4.540
394	Experiment No. 488	22.64	9.98	43.73	23.65	4.200
395	Experiment No. 489	22.30	7.18	48.08	22.44	4.930
410	Experiment No. 490	30.27	10.83	32.45	26.45	4.874
411	Experiment No. 491	29.18	10.38	31.11	29.33	4.330
412	Experiment No. 492	27.94	16.19	30.29	25.58	4.520

The urine of each subject was collected during each experimental period, beginning with 7 a. m. of the first day of the experiment and ending at 7 a. m. of the first day immediately following the experiment. The total amount and specific gravity of the urine and the percentage of nitrogen in it were determined for each day. These data are here given:

TABLE 4.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with Oregon and Oklahoma wheat bread.*

Sample No.	Subject No.	Whence obtained.	Total amount voided.	Specific gravity.	Nitrogen
		Experiment No. 469:	*Grams.*		*Per cent.*
279	1	First day	1,119	1.023	1.30
282	1	Second day	972	1.025	1.45
285	1	Third day	685	1.029	1.90
288	1	Fourth day	1.759	1.018	1.21
		Experiment No. 470:			
280	2	First day	747	1.027	1 45
283	2	Second day	730	1.030	1.79
286	2	Third day	515	1.030	1.96
289	2	Fourth day	1.014	1.027	1.84

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 21, p. 58, 143, pp. 66–76.

TABLE 4.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with Oregon and Oklahoma wheat bread*—Continued.

Sample No.	Subject No.	Whence obtained.	Total amount voided.	Specific gravity.	Nitrogen.
		Experiment No. 471:	*Grams.*		*Per cent.*
281	3	First day	464	1.029	1.55
284	3	Second day	728	1.032	1.85
287	3	Third day	697	1.025	1.62
290	3	Fourth day	965	1.026	1.64
		Experiment No. 472:			
296	1	First day	1,386	1.020	1.31
299	1	Second day	979	1.025	1.49
302	1	Third day	1,066	1.023	1.55
305	1	Fourth day	1,775	1.020	1.26
		Experiment No. 473:			
297	2	First day	888	1.023	1.24
300	2	Second day	1,398	1.015	.95
303	2	Third day	638	1.025	1.56
306	2	Fourth day	1,196	1.029	1.24
		Experiment No. 474:			
298	3	First day	948	1.018	1.11
301	3	Second day	774	1.022	1.21
304	3	Third day	1,252	1.021	1.24
307	3	Fourth day	1,314	1.020	1.24
		Experiment No. 475:			
313	1	First day	691	1.023	1.38
316	1	Second day	876	1.027	1.42
319	1	Third day	911	1.029	1.46
322	1	Fourth day	1,533	1.028	1.52
		Experiment No. 476:			
314	2	First day	613	1.028	1.37
317	2	Second day	794	1.027	1.66
320	2	Third day	689	1.026	1.44
323	2	Fourth day	1,505	1.025	1.19
		Experiment No. 477:			
315	3	First day	743	1.025	1.44
318	3	Second day	714	1.027	1.42
321	3	Third day	857	1.029	1.69
324	3	Fourth day	1,188	1.020	1.20
		Experiment No. 478:			
330	1	First day	1,327	1.024	1.53
333	1	Second day	1,592	1.026	1.60
336	1	Third day	1,891	1.022	1.56
339	1	Fourth day	2,361	1.022	1.52
		Experiment No. 479:			
331	2	First day	989	1.027	1.60
334	2	Second day	878	1.030	1.93
337	2	Third day	892	1.029	1.96
340	2	Fourth day	2,236	1.019	1.32
		Experiment No. 480:			
332	3	First day	1,103	1.022	1.26
335	3	Second day	1,114	1.020	1.37
338	3	Third day	1,148	1.023	1.50
341	3	Fourth day	1,193	1.022	1.44
		Experiment No. 481:			
347	1	First day	1,220	1.023	1.29
350	1	Second day	1,250	1.027	1.63
353	1	Third day	1,395	1.027	1.76
356	1	Fourth day	2,165	1.025	1.66
		Experiment No. 482:			
348	2	First day	839	1.029	1.48
351	2	Second day	726	1.027	1.86
354	2	Third day	727	1.029	1.77
357	2	Fourth day	1,312	1.030	2.17
		Experiment No. 483:			
349	3	First day	2,079	1.015	.55
352	3	Second day	1,749	1.018	.98
355	3	Third day	1,352	1.019	1.18
358	3	Fourth day	1,086	1.023	1.44
		Experiment No. 484:			
364	1	First day	1,841	1.021	1.15
367	1	Second day	1,440	1.025	1.48
370	1	Third day	1,520	1.025	1.54
373	1	Fourth day	2,582	1.023	1.61
		Experiment No. 485:			
365	2	First day	944	1.026	1.53
368	2	Second day	1,102	1.029	1.85
371	2	Third day	801	1.027	1.96
374	2	Fourth day	781	1.029	1.92
		Experiment No. 486:			
366	3	First day	1,327	1.018	1.02
369	3	Second day	1,336	1.019	1.06
372	3	Third day	1,040	1.022	1.31
375	3	Fourth day	1,217	1.021	1.37

TABLE 4.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with Oregon and Oklahoma wheat bread*—Continued.

Sample No.	Subject No.	Whence obtained.	Total amount voided.	Specific gravity.	Nitrogen.
		Experiment No. 487:	*Grams.*		*Per cent.*
381	1	First day	1,195		
384	1	Second day	1,354	[a] 1.026	[a] 1.47
387	1	Third day	1,924		
		Experiment No. 488:			
382	2	First day	745		
385	2	Second day	804	[a] 1.028	[a] 2.08
388	2	Third day	1,467		
		Experiment No. 489:			
383	3	First day	1,099		
386	3	Second day	1,203	[a] 1.024	[a] 1.57
389	3	Third day	721		
		Experiment No. 490:			
398	1	First day	1,548		
401	1	Second day	1,612	[a] 1.026	[a] 1.62
404	1	Third day	1,753		
		Experiment No. 491:			
399	2	First day	507		
402	2	Second day	1,049	[a] 1.028	[a] 1.81
405	2	Third day	1,042		
		Experiment No. 492:			
400	3	First day	1,060		
403	3	Second day	1,070	[a] 1.023	[a] 1.46
406	3	Third day	1,412		

[a] Composite sample.

EXPERIMENTAL METHODS.

The method followed in making the digestion experiments was similar to that explained in detail in a former bulletin.[a] A simple diet of bread and milk was eaten, each material being consumed ad libitum, but the amount taken at each meal weighed and recorded. The digestibility of the nutrients of the total diet was determined from the quantity of each in the food and feces. The digestibility of the nutrients in the bread alone was computed by assuming coefficients of digestibility for the nutrients of the milk, as explained beyond.

The bread was made by the short process of fermentation—that is, with a large proportion of yeast. Comparatively large amounts of salt and water were used in mixing the dough, but neither milk nor shortening. For each experiment two bakings were made, the subjects preferring bread twenty-four hours old to fresh bread.

The digestibility of the total diet of bread and milk was calculated from the difference between the total nutrients in the food consumed and those in the feces.[b] The digestibility of the bread alone was cal-

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

[b] It will be observed that, although the factor 5.70 is more nearly correct for the calculation of the percentage of protein in cereals from the percentage of nitrogen determined, the factor 6.25 has been used in these experiments. The same factor has been used for milk protein, in which case it is correct. The use of this factor for cereals also is merely for convenience in the computations of the digestibility of the protein. If different factors were used for the protein of different foods, the same differences in factors would have to be observed in estimating protein of feces, and this would involve complicated computations. Since the coefficient of digestibility would be the same whichever factor is used, provided the same factor is used for protein of both food and feces, the factor 6.25 has been used uniformly for convenience.

culated, as in former work, by assuming that 97 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrates of the milk were digested. These values have been deduced from the results of a large number of digestion experiments with both ordinary and special diets.[a] The undigested nutrients of the milk, as calculated by the use of these factors, subtracted from the total nutrients in the feces give the estimated undigested nutrients from bread, and these subtracted from the total nutrients of the bread give the digestible nutrients in bread. These last divided by the total nutrients in the bread and multiplied by 100 give the percentages or coefficients of digestibility of bread alone.

The amounts of energy given for the bread and milk and the total feces were determined by multiplying the total weight of each material by its heat of combustion as determined with the bomb calorimeter. The proportion of energy in total food estimated to be available to the body was found by dividing the energy of the total digested food by the energy of the total food.

In order to estimate the amounts of energy in the feces from bread alone, the energy of the feces from food other than bread (in this case milk) was computed by means of factors. Previous investigations[b] have shown that the heat of combustion of the nutrients in dairy products are, per gram, as follows: For protein, 5.65 calories; for fat, 9.25 calories; and for carbohydrates, 3.9 calories. By multiplying the weights of the nutrients in the feces from food other than bread by these factors and adding the products an estimated energy value is obtained. It is known, however, as pointed out on page 13, that the energy of food materials, when estimated by the use of factors, varies somewhat from the value obtained by actual combustion in the bomb calorimeter. A similar variation is found in the total feces, and undoubtedly would be found in the feces from a portion of the diet could a separation be effected and the actual heat of combustion determined. In order to approximate this latter value as closely as possible, the energy of the total feces was also calculated by means of factors. In this case, however, since the total feces were made up of the residues from two foods—milk and bread—the factors used were those computed[b] for a mixed diet, these values being per gram as follows: Protein, 5.65 calories; fat, 9.4 calories, and carbohydrates, 4.15 calories. It was then assumed that the difference in values existing between the energy of the total feces as thus computed and as actually determined is proportional to the presumed difference in value between the energy of the feces from food other than bread as computed and the value which would be obtained could an actual determination be made. In other words, the calculated energy of the total feces is to the determined

[a] Connecticut Storrs Station Rpt. 1899, pp. 84–86.
[b] Connecticut Storrs Station Rpt. 1899, p. 104.

energy of the total feces as the calculated energy of the feces from food other than bread is to x, the value desired. For example, in experiment No. 469 the computed heat of combustion of the total feces was 745 calories, while the value obtained in the calorimeter was 787 calories. The computed heat of combustion of the feces from food other than bread was 242 calories. The proportion was therefore as follows: $745:787=242:x$, or $x=257$ calories. The heat of combustion of the feces from bread alone was found by subtracting this value from the determined heat of combustion of the total feces (787 calories). This result (530 calories) subtracted from the total heat of combustion of bread (4,770 calories) gives the heat of combustion of the estimated digestible nutrients in bread (4,240 calories), which divided by the total heat of combustion of bread (4,770 calories) and multiplied by 100 gives the proportion (88.9 per cent) of the total energy of the bread estimated to be contained in the digestible nutrients.

The value as thus determined, however, does not represent the energy actually available to the body, since a portion of the energy of the digested nutrients is lost in the incompletely oxidized material of the urine. The proportion of the energy of the total food and of the bread alone which was actually available to the body was computed as in previous investigations, according to the assumption that the amount of the energy lost in the organic matter of the urine was 1.25 calories per gram of digestible protein. Thus in experiment No. 469 the total amount of energy lost in the urine was found by multiplying the digestible protein in total food (401.4 grams) by 1.25, which gave 502 calories. This product was subtracted from the energy of the total food digested (9,756 calories), and the difference (9,254 calories) divided by the energy in the total food (10,543 calories) and multiplied by 100 gave the proportion of energy in the total food actually available to the body (87.8 per cent). The proportion of energy in bread alone which was actually available (87 per cent) was obtained in like manner by dividing the difference between the estimated energy in the bread digested (4,240 calories) and the energy lost in the urine ($70.9\times1.25=89$ calories) by the total energy in the bread (4,770 calories).

As pointed out in former reports, it is well known that the digestion coefficients obtained in the manner described are relative rather than absolute. It is believed, however, that while the figures for a single digestion experiment may be open to criticism, the results of a series of experiments as reported in this bulletin are comparable because whatever error is introduced in one experiment is common to all. Since the determinations of dry matter, nitrogen, and energy are known to be of greater accuracy than the other chemical data included, particular attention is given to the results and conclusions based upon these values.

DETAILS OF THE DIGESTION EXPERIMENTS.

In these investigations with Oregon and Oklahoma wheats two series of digestion experiments were carried on, each series consisting of three experiments with each of three subjects. The diet consisted of milk, and bread made from the different grades of flour. In the first series the first three experiments were carried on simultaneously, the three subjects being fed on bread from the entire-wheat flour milled from the Oregon wheat, and in addition sufficient milk to make the diet palatable. Three more experiments followed in which bread from the straight-grade flour was substituted for the entire-wheat bread, and, finally, in three more experiments Graham bread was used. In the second series the experiments were repeated in a similar way with bread made from the Oklahoma wheat.

Besides these, two additional experiments were made with each subject in order to determine the influence of the bran and germ upon the completeness of digestion. In the first of these the diet consisted of bread from bran flour, eaten with some milk. In the second, bread from germ flour was substituted for the bran flour bread.

The total number of separate experiments was therefore twenty-four. The period of duration in each of the experiments with the ordinary flours was four days, or twelve meals; in the experiments with the bran and germ flour breads it was three days, or nine meals.

The subjects, designated in these experiments as Nos. 1, 2, and 3, were young men in good health. One was employed as a laborer on the university farm at field work and the care of stock, and the other two devoted part of their time to university studies with several hours each day of miscellaneous muscular work.

EXPERIMENTS WITH ENTIRE-WHEAT, STRAIGHT-GRADE, AND GRAHAM FLOURS (BREAD) FROM OREGON WHEAT.

The following tables, Nos. 5 to 13, give the data of the nine experiments in the series with Oregon wheat. Accompanying each table are statistics regarding the diet, subject, and date of the experiment, and a summary of the data of income and outgo of nitrogen during the experimental period.

DIGESTION EXPERIMENT NO. 469.

Kind of food.—Milk, and bread made from Oregon entire-wheat flour.

Subject.—Man No. 1. Farm hand employed at average farm labor.

Weight.—At the beginning of the experiment 180 pounds; at the close 180 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast, March 11, 1903.

TABLE 5.—*Results of digestion experiment No. 469.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
277	Bread	1,859.0	106.0	20.3	973.9	16.2	4,770
278	Milk	9,412.0	340.7	336.9	354.8	64.9	5,773
	Total		446.7	357.2	1,328.7	81.1	10,543
291	Feces (water-free)	175.0	45.3	22.4	67.2	40.1	787
	Estimated feces from food other than bread		10.2	16.9	7.1		257
	Estimated feces from bread		35.1		60.1		530
	Total amount digested		401.4	334.8	1,261.5	41.0	9,756
	Estimated digestible nutrients in bread		70.9		913.8		4,240
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		89.8	93.7	94.9	50.6	92.5
	Estimated coefficients of digestibility of bread alone		66.9		93.8		88.9
	Proportion of energy actually available to the body:						
	In total food						87.8
	In bread alone						87.0

During this experiment the subject eliminated 4,535 grams urine, containing 62.94 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 17.87 grams; outgo in urine 15.74 grams; and in feces 1.81 grams; implying a gain of 0.32 gram nitrogen, corresponding to 2 grams protein.

DIGESTION EXPERIMENT NO. 470.

Kind of food.—Milk, and bread made from Oregon entire-wheat flour.

Subject.—Man No. 2. University student employed about two hours per day at miscellaneous manual labor; walked about 2 miles daily.

Weight.—At the beginning of the experiment 159.25 pounds; at the close 158.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 11, 1903.

TABLE 6.—*Results of digestion experiment No. 470.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
277	Bread	2,623.0	149.5	28.6	1,374.2	22.8	6,731
278	Milk	7,998.0	289.5	286.3	301.5	55.2	4,906
	Total		439.0	314.9	1,675.7	78.0	11,637
292	Feces (water-free)	176.0	42.3	16.3	80.6	36.8	785
	Estimated feces from food other than bread		8.7	14.3	6.0		221
	Estimated feces from bread		33.6		74.6		564
	Total amount digested		396.7	298.6	1,595.1	41.2	10,852
	Estimated digestible nutrients in bread		115.9		1,299.6		6,167

TABLE 6.—*Results of digestion experiment No. 470*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 90.4	*Per cent.* 94.8	*Per cent.* 95.2	*Per cent.* 52.9	*Per cent.* (93.3)
	Estimated coefficients of digestibility of bread alone		77.5		94.6		(91.6)
	Proportion of energy actually available to the body:						
	In total food						89.0
	In bread alone						89.5

During this experiment the subject eliminated 3,006 grams urine containing 52.65 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 17.56 grams; outgo in urine 13.16 grams; and in feces 1.69 grams; implying a gain of 2.71 grams nitrogen, corresponding to 16.9 grams protein.

DIGESTION EXPERIMENT NO. 471.

Kind of food.—Milk, and bread made from Oregon entire-wheat flour.

Subject.—Man No. 3. University student employed one-third of the time at office work, with exercise the same as subject No. 2.

Weight.—At the beginning of the experiment 158 pounds; at the close 155 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 11, 1903.

TABLE 7.—*Results of digestion experiment No. 471.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
277	Bread	1,811.0	103.2	19.7	948.8	15.8	4,647
278	Milk	5,302.4	192.0	189.8	199.9	36.6	3,253
	Total		295.2	209.5	1,148.7	52.4	7,900
293	Feces (water-free)	150.0	37.9	16.9	62.6	32.6	675
	Estimated feces from food other than bread		5.8	9.5	4.0		147
	Estimated feces from bread		32.1		58.6		528
	Total amount digested		257.3	192.6	1,086.1	19.8	7,225
	Estimated digestible nutrients in bread		71.1		890.2		4,119
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		87.2	91.9	94.6	37.7	(91.5)
	Estimated coefficients of digestibility of bread alone		68.9		93.8		(88.6)
	Proportion of energy actually available to the body:						
	In total food						87.4
	In bread alone						86.7

During this experiment the subject eliminated 2,854 grams urine, containing 47.79 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 11.81 grams; outgo in urine 11.95 grams; and in feces 1.52 grams; implying a loss of 1.66 grams nitrogen, corresponding to 10.4 grams protein.

DIGESTION EXPERIMENT NO. 472.

Kind of food.—Milk, and bread made from Oregon straight-grade flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 174.5 pounds; at the close 174 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 26, 1903.

TABLE 8.—*Results of digestion experiment No. 472.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
294	Bread	2,544.0	137.6	22.6	1,471.7	22.9	7,034
295	Milk	9,153.8	271.0	408.3	408.3	76.9	7,003
	Total	.....	408.6	430.9	1,880.0	99.8	14,037
308	Feces (water-free)	117.0	28.0	14.8	37.0	37.2	540
	Estimated feces from food other than bread	.....	8.1	20.4	8.2	.....	320
	Estimated feces from bread	.....	19.9	.....	28.8	.....	220
	Total amount digested	.....	380.6	416.1	1,843.0	62.6	13,497
	Estimated digestible nutrients in bread	.....	117.7	.....	1,442.9	.....	6,814
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	93.1	96.6	98.0	62.7	(96.2)
	Estimated coefficients of digestibility of bread alone	.....	85.6	.....	98.0	.....	(96.9)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	92.8
	In bread alone	.....	.....	.....	.....	.....	94.8

During this experiment the subject eliminated 5,206 grams urine, containing 71.64 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 16.34 grams; outgo in urine 17.91 grams; and in feces 1.12 grams; implying a loss of 2.69 grams nitrogen, corresponding to 16.8 grams protein.

DIGESTION EXPERIMENT NO. 473.

Kind of food.—Milk, and bread made from Oregon straight-grade flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 152.5 pounds; at the close 154 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 26, 1903.

TABLE 9.—*Results of digestion experiment No. 473.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
294	Bread	3,045.0	164.7	27.1	1,761.5	27.4	8,419
295	Milk	8,034.0	237.8	358.3	358.3	67.5	6,147
	Total	.....	402.5	385.4	2,119.8	94.9	14,566
309	Feces (water-free)	97.0	24.6	11.0	27.0	34.4	384
	Estimated feces from food other than bread	.....	7.1	17.9	7.2	.....	255
	Estimated feces from bread	.....	17.5	.....	19.8	.....	129
	Total amount digested	.....	377.9	374.4	2,092.8	60.5	14,182
	Estimated digestible nutrients in bread	.....	147.2	.....	1,741.7	.....	8,290
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	93.9	97.2	98.7	63.8	(97.4)
	Estimated coefficients of digestibility of bread alone	.....	89.4	.....	98.9	.....	(98.5)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	94.1
	In bread alone	.....	.....	.....	.....	.....	96.3

During this experiment the subject eliminated 4,120 grams urine, containing 49.07 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 16.10 grams; outgo in urine 12.27 grams; and in feces 0.98 gram; implying a gain of 2.85 grams nitrogen, corresponding to 17.8 grams protein.

DIGESTION EXPERIMENT NO. 474.

Kind of food.—Milk, and bread made from Oregon straight-grade flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 155 pounds; at the close 155.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 26, 1903.

TABLE 10.—*Results of digestion experiment No. 474.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
294	Bread	2,463.0	133.2	21.9	1,424.8	22.2	6,810
295	Milk	6,192.0	183.3	276.2	276.2	52.0	4,737
	Total	.....	316.5	298.1	1,701.0	74.2	11,547
310	Feces (water-free)	111.0	32.4	11.1	37.0	30.5	469
	Estimated feces from food other than bread	.....	5.5	13.8	5.5	.....	192
	Estimated feces from bread	.....	26.9	.....	31.5	.....	277
	Total amount digested	.....	284.1	287.0	1,664.0	43.7	11,078

TABLE 10.—*Results of digestion experiment No. 474*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Estimated digestible nutrients in bread	*Grams.*	*Grams.* 106.3	*Grams.*	*Grams.* 1,393.3	*Grams.*	*Calories.* 6,533
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		89.8	96.3	97.8	58.9	(95.9)
	Estimated coefficients of digestibility of bread alone		79.8		97.8		(95.9)
	Proportion of energy actually available to the body:						
	In total food						92.9
	In bread alone						94.0

During this experiment the subject eliminated 4,288 grams urine, containing 51.71 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 12.66 grams; outgo in urine 12.93 grams; and in feces 1.29 grams; implying a loss of 1.56 grams nitrogen, corresponding to 9.8 grams protein.

DIGESTION EXPERIMENT NO. 475.

Kind of food.—Milk, and bread made from Oregon Graham flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 174 pounds; at the close 174 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 30, 1903.

TABLE 11.—*Results of digestion experiment No. 475.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
311	Bread	3,431.0	209.6	38.4	1,807.5	52.8	8,790
312	Milk	8,194.0	145.0	357.3	436.7	65.6	5,581
	Total		354.6	395.7	2,244.2	118.4	14,371
325	Feces (water-free)	388.2	87.0	43.5	188.4	69.3	1,777
	Estimated feces from food other than bread		4.4	17.9	8.7		237
	Estimated feces from bread		82.6		179.7		1,540
	Total amount digested		267.6	352.2	2,055.8	49.1	12,594
	Estimated digestible nutrients in bread		127.0		1,627.8		7,250
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		75.5	89.0	91.6	41.5	(87.6)
	Estimated coefficients of digestibility of bread alone		60.6		90.1		(82.5)
	Proportion of energy actually available to the body:						
	In total food						85.3
	In bread alone						80.7

During this experiment the subject eliminated 4,011 grams urine, containing 58.58 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 14.19 grams; outgo in urine 14.65 grams; and in feces 3.48 grams; implying a loss of 3.94 grams nitrogen, corresponding to 24.6 grams protein.

DIGESTION EXPERIMENT NO. 476.

Kind of food.—Milk, and bread made from Oregon Graham flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 154 pounds; at the close 156 pounds.

Duration.—Four days, with 12 meals, beginning with breakfast March 30, 1903.

TABLE 12.—*Results of digestion experiment No. 476.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
311	Bread	2,736.0	167.2	30.6	1,441.3	42.1	7,010
312	Milk	7,894.8	139.7	344.2	420.8	63.2	5,377
	Total		306.9	374.8	1,862.1	105.3	12,387
326	Feces (water-free)	288.5	62.2	30.2	139.8	56.3	1,239
	Estimated feces from food other than bread		4.2	17.2	8.4		220
	Estimated feces from bread		58.0		131.4		1,019
	Total amount digested		244.7	344.6	1,722.3	49.0	11,148
	Estimated digestible nutrients in bread		109.2		1,209.9		5,991
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		79.7	91.9	92.5	46.5	(90.0)
	Estimated coefficients of digestibility of bread alone		65.3		90.9		(85.5)
	Proportion of energy actually available to the body:						
	In total food						87.5
	In bread alone						83.5

During this experiment the subject eliminated 3,601 grams urine, containing 49.41 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 12.28 grams; outgo in urine 12.35 grams; and in feces 2.49 grams; implying a loss of 2.56 grams nitrogen, corresponding to 16 grams protein.

DIGESTION EXPERIMENT NO. 477.

Kind of food.—Milk, and bread made from Oregon Graham flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 154.5 pounds; at the close 151.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast March 30, 1903.

TABLE 13.—*Results of digestion experiment No. 477.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
311	Bread	1,563.0	95.5	17.5	823.4	24.1	4,004
312	Milk	6,398.4	113.2	279.0	341.0	51.2	4,358
	Total		208.7	296.5	1,164.4	75.3	8,362
327	Feces (water-free)	185.3	60.2	22.0	67.7	35.4	822
	Estimated feces from food other than bread		3.4	14.0	6.8		173
	Estimated feces from bread		56.8		60.9		649
	Total amount digested		148.5	274.5	1,096.7	39.9	7,540
	Estimated digestible nutrients in bread		38.7		762.5		3,355
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		71.1	92.6	94.2	53.0	(90.2)
	Estimated coefficients of digestibility of bread alone		40.5		92.6		(83.8)
	Proportion of energy actually available to the body:						
	In total food						88.0
	In bread alone						82.6

During this experiment the subject eliminated 3,502 grams urine, containing 49.58 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 8.35 grams; outgo in urine 12.40 grams; and in feces 2.41 grams; implying a loss of 6.46 grams nitrogen, corresponding to 40.4 grams protein.

EXPERIMENTS WITH STRAIGHT-GRADE, ENTIRE-WHEAT, AND GRAHAM FLOURS (BREAD) FROM OKLAHOMA WHEAT.

The data of the experiments with bread made from the three grades of flour milled from the Oklahoma wheat are given in Tables 14 to 22, which follow.

DIGESTION EXPERIMENT NO. 478.

Kind of food.—Milk, and bread made from Oklahoma straight-grade flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 173 pounds; at the close 175 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 8, 1903.

TABLE 14.—*Results of digestion experiment No. 478.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
328	Bread	3,558.0	360.4	22.8	1,819.6	15.6	9,902
329	Milk	11,625.0	337.1	428.9	541.7	96.5	7,476
	Total		697.5	451.7	2,361.3	112.1	17,378

TABLE 14.—*Results of digestion experiment No. 478*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
342	Feces (water-free)	182.0	45.3	17.0	71.2	48.5	879
	Estimated feces from food other than bread		10.1	21.4	10.8		368
	Estimated feces from bread		35.2		60.4		511
	Total amount digested		652.2	434.7	2,290.1	63.6	16,499
	Estimated digestible nutrients in bread		325.2		1,759.2		9,391
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		93.5	96.3	97.0	56.7	(94.9)
	Estimated coefficients of digestibility of bread alone		90.2		96.7		(94.8)
	Proportion of energy actually available to the body:						
	In total food						90.3
	In bread alone						90.7

During this experiment the subject eliminated 7,171 grams urine containing 111.16 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 27.90 grams; outgo in urine 27.79 grams; and in feces 1.81 grams; implying a loss of 1.70 grams nitrogen, corresponding to 10.6 grams protein.

DIGESTION EXPERIMENT NO. 479.

Kind of food.—Milk, and bread made from Oklahoma straight-grade flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 156 pounds; at the close 162 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 8, 1903.

TABLE 15.—*Results of digestion experiment No. 479.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
328	Bread	2,673.0	270.8	17.1	1,367.0	11.7	7,439
329	Milk	7,513.0	217.9	277.2	350.1	62.4	4,829
	Total		488.7	294.3	1,717.1	74.1	12,268
343	Feces (water-free)	98.0	28.4	7.5	31.4	30.7	404
	Estimated feces from food other than bread		6.5	13.9	7.0		215
	Estimated feces from bread		21.9		24.4		189
	Total amount digested		460.3	286.8	1,685.7	43.4	11,864
	Estimated digestible nutrients in bread		248.9		1,342.6		7,250
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		94.2	97.4	98.2	58.6	(96.7)
	Estimated coefficients of digestibility of bread alone		91.9		98.2		(97.5)
	Proportion of energy actually available to the body:						
	In total food						[illegible].0
	In bread alone						[illegible].3

During this experiment the subject eliminated 4,995 grams urine, containing 79.77 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 19.55 grams; outgo in urine 19.94 grams; and in feces 1.14 grams; implying a loss of 1.53 grams nitrogen, corresponding to 9.6 grams protein.

DIGESTION EXPERIMENT NO. 480.

Kind of food.—Milk, and bread made from Oklahoma straight-grade flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 152 pounds; at the close 152 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 8, 1903.

TABLE 16.—*Results of digestion experiment No. 480.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
328	Bread	2,549.0	258.2	16.3	1,303.5	11.2	7,094
329	Milk	6,961.0	201.9	256.9	324.4	57.8	4,474
	Total	.....	460.1	273.2	1,627.9	69.0	11,568
344	Feces (water-free)	104.0	30.3	14.4	31.0	28.3	443
	Estimated feces from food other than bread	.....	6.0	12.8	6.5	.....	182
	Estimated feces from bread	.....	24.3	.....	24.5	.....	261
	Total amount digested	.....	429.8	258.8	1,596.9	40.7	11,125
	Estimated digestible nutrients in bread	.....	233.9	.....	1,279.0	.....	6,833
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	93.4	94.7	98.1	59.0	(96.2)
	Estimated coefficients of digestibility of bread alone	.....	90.6	.....	98.1	.....	(96.3)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	91.5
	In bread alone	.....	.....	.....	.....	.....	92.2

During this experiment the subject eliminated 4,558 grams urine, containing 63.56 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 18.40 grams; outgo in urine 15.89 grams; and in feces 1.21 grams; implying a gain of 1.30 grams nitrogen, corresponding to 8.1 grams protein.

DIGESTION EXPERIMENT NO. 481.

Kind of food.—Milk, and bread made from Oklahoma entire-wheat flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 174 pounds; at the close 173.75 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 15, 1903.

TABLE 17.—*Results of digestion experiment No. 481.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
345	Bread	3,597.0	381.3	37.4	1,658.6	33.8	9,762
346	Milk	11,569.0	332.0	497.5	532.1	81.0	8,203
	Total	.....	713.3	534.9	2,190.7	114.8	17,965
359	Feces (water-free)	369.0	102.5	24.7	182.8	59.0	1,773
	Estimated feces from food other than bread	.....	10.0	24.9	10.6	.....	370
	Estimated feces from bread	.....	92.5	.....	172.2	.....	1,403
	Total amount digested	.....	610.8	510.2	2,007.9	55.8	16,192
	Estimated digestible nutrients in bread	.....	288.8	.....	1,486.4	.....	8,359
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	85.6	95.4	91.7	48.6	(90.1)
	Estimated coefficients of digestibility of bread alone	.....	75.7	.....	89.6	.....	(85.6)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	85.9
	In bread alone	.....	.....	.....	.....	.....	81.9

During this experiment the subject eliminated 6,030 grams urine, containing 96.61 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 28.53 grams; outgo in urine 24.15 grams; and in feces 4.10 grams; implying a gain of 0.28 gram nitrogen, corresponding to 1.8 grams protein.

DIGESTION EXPERIMENT NO. 482.

Kind of food.—Milk, and bread made from Oklahoma entire-wheat flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 155.5 pounds; at the close 155 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 15, 1903.

TABLE 18.—*Results of digestion experiment No. 482.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
345	Bread	2,449.0	259.6	25.5	1,129.2	23.0	6,646
346	Milk	7,730.0	221.9	332.4	355.6	54.1	5,481
	Total	.....	481.5	357.9	1,484.8	77.1	12,127
360	Feces (water-free)	193.5	47.2	14.4	97.3	34.6	860
	Estimated feces from food other than bread	.....	6.7	16.6	7.1	.....	235
	Estimated feces from bread	.....	40.5	.....	90.2	.....	625
	Total amount digested	.....	434.3	343.5	1,387.5	42.5	11,267
	Estimated digestible nutrients in bread	.....	219.1	.....	1,039.0	.....	6,021

TABLE 18.—*Results of digestion experiment No. 482*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 90.2	*Per cent.* 96.0	*Per cent.* 93.4	*Per cent.* 55.1	*Per cent.* (92.9)
	Estimated coefficients of digestibility of bread alone		84.4		92.0		(90.6)
	Proportion of energy actually available to the body:						
	In total food						88.4
	In bread alone						86.5

During this experiment the subject eliminated 3,604 grams urine, containing 67.26 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 19.26 grams; outgo in urine 16.82 grams; and in feces 1.89 grams; implying a gain of 0.55 gram nitrogen, corresponding to 3.4 grams protein.

DIGESTION EXPERIMENT NO. 483.

Kind of food.—Milk, and bread made from Oklahoma entire-wheat flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 154.5 pounds; at the close 151.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 15, 1903.

TABLE 19.—*Results of digestion experiment No. 483.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
345	Bread	1,731.0	183.5	18.0	798.1	16.3	4,698
346	Milk	8,173.5	234.6	351.5	376.0	57.2	5,795
	Total		418.1	369.5	1,174.1	73.5	10,493
361	Feces (water-free)	193.5	46.2	20.1	87.4	39.8	873
	Estimated feces from food other than bread		7.0	17.6	7.5		247
	Estimated feces from bread		39.2		79.9		626
	Total amount digested		371.9	349.4	1,086.7	33.7	9,620
	Estimated digestible nutrients in bread		144.3		718.2		4,072
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		89.0	94.6	92.6	45.9	(91.7)
	Estimated coefficients of digestibility of bread alone		78.7		90.0		(86.7)
	Proportion of energy actually available to the body:						
	In total food						87.3
	In bread alone						82.9

During this experiment the subject eliminated 6,266 grams urine, containing 60.17 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 16.72 grams; outgo in urine 15.04 grams; and in feces 1.85 grams; implying a loss of 0.17 gram nitrogen, corresponding to 1.1 grams protein.

DIGESTION EXPERIMENT NO. 484.

Kind of food.—Milk, and bread made from Oklahoma Graham flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 175 pounds; at the close 173.75 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 20, 1903.

TABLE 20.—*Results of digestion experiment No. 484.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
362	Bread	3,635.0	387.1	40.7	1,620.5	52.7	9,145
363	Milk	12,281.0	361.1	719.7	423.7	106.9	8,473
	Total		748.2	760.4	2,044.2	159.6	17,618
376	Feces (water-free)	486.0	111.0	49.2	242.7	83.1	2,297
	Estimated feces from food-other than bread		10.8	36.0	8.5		470
	Estimated feces from bread		100.2		234.2		1,827
	Total amount digested		637.2	711.2	1,801.5	76.5	15,321
	Estimated digestible nutrients in bread		286.9		1,386.3		7,318
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		85.2	93.5	88.1	47.9	(87.0)
	Estimated coefficients of digestibility of bread alone		74.1		85.6		(80.0)
	Proportion of energy actually available to the body:						
	In total food						82.4
	In bread alone						76.1

During this experiment the subject eliminated 7,383 grams urine, containing 107.46 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 29.93 grams; outgo in urine 26.87 grams; and in feces 4.44 grams; implying a loss of 1.38 grams nitrogen, corresponding to 8.6 grams protein.

DIGESTION EXPERIMENT NO. 485.

Kind of food.—Milk, and bread made from Oklahoma Graham flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 155 pounds; at the close 156 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 20, 1903.

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TABLE 21.—*Results of digestion experiment No. 485.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
362	Bread	2,672.0	284.6	29.9	1,191.2	38.7	6,723
363	Milk	7,234.3	212.7	423.9	249.5	63.0	4,991
	Total		497.3	453.8	1,440.7	101.7	11,714
377	Feces (water-free)	254.0	57.1	21.6	134.5	40.8	834
	Estimated feces from food other than bread		6.4	21.2	5.0		193
	Estimated feces from bread		50.7		129.5		641
	Total amount digested		440.2	432.2	1,306.2	60.9	10,880
	Estimated digestible nutrients in bread		233.9		1,061.7		6,082
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		88.5	95.2	90.7	59.9	(92.9)
	Estimated coefficients of digestibility of bread alone		82.2		89.1		(90.5)
	Proportion of energy actually available to the body:						
	In total food						88.2
	In bread alone						86.1

During this experiment the subject eliminated 3,628 grams urine, containing 65.53 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 19.89 grams; outgo in urine 16.38 grams; and in feces 2.28 grams; implying a gain of 1.23 grams nitrogen, corresponding to 7.7 grams protein.

DIGESTION EXPERIMENT NO. 486.

Kind of food.—Milk, and bread made from Oklahoma Graham flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 153.5 pounds; at the close 152.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 20, 1903.

TABLE 22.—*Results of digestion experiment No. 486.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
362	Bread	1,661.0	176.9	18.6	740.5	24.1	4,179
363	Milk	7,089.8	208.4	415.5	244.6	61.7	4,891
	Total		385.3	434.1	985.1	85.8	9,070
378	Feces (water-free)	210.0	49.4	24.2	97.9	38.5	935
	Estimated feces from food other than bread		6.2	20.8	4.9		251
	Estimated feces from bread		43.2		93.0		684
	Total amount digested		335.9	409.9	887.2	47.3	8,135
	Estimated digestible nutrients in bread		133.7		647.5		3,495
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		87.2	94.4	90.1	55.1	(89.7)

TABLE 22.—*Results of digestion experiment No. 486*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Estimated coefficients of digestibility of bread alone		*Per cent.* 75.6	*Per cent.*	*Per cent.* 87.4	*Per cent.*	*Per cent.* (83.6)
	Proportion of energy actually available to the body:						
	In total food						85.1
	In bread alone						79.6

During this experiment the subject eliminated 4,920 grams urine, containing 57.99 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 15.41 grams; outgo in urine 14.50 grams; and in feces 1.98 grams, implying a loss of 1.07 grams nitrogen, corresponding to 6.7 grams protein.

SUMMARY OF RESULTS OBTAINED WITH BREAD FROM DIFFERENT GRADES OF FLOUR.

The results of the experiments showing the digestibility of the nutrients and availability of the energy of the three grades of flour are summarized in the following tables. Table 23 shows the percentages for the total food (bread and milk) and Table 24 the values computed for bread alone in the manner previously described (p. 18). These latter values are of particular interest.

TABLE 23.—*Digestibility of nutrients and availability of energy of total food.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
		Experiments with Oregon wheat.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
469	1	Milk and entire-wheat flour bread	89.8	93.7	94.9	87.8
470	2	.....do	90.4	94.8	95.2	89.0
471	3	.....do	87.2	91.9	94.6	87.4
		Average	89.1	93.5	94.9	88.1
472	1	Milk and straight-grade flour bread	93.1	96.6	98.0	92.8
473	2	.....do	93.9	97.2	98.7	94.1
474	3	.....do	89.8	96.3	97.8	92.9
		Average	92.3	96.7	98.2	93.3
475	1	Milk and Graham flour bread	75.5	89.0	91.6	85.3
476	2	.....do	79.7	91.9	92.5	87.5
477	3	.....do	[a] 71.1	92.6	94.2	88.0
		Average	77.6	91.2	92.8	86.9
		Experiments with Oklahoma wheat.				
481	1	Milk and entire-wheat flour bread	85.6	95.4	91.7	85.9
482	2	.....do	90.2	96.0	93.4	88.4
483	3	.....do	89.0	94.6	92.6	87.3
		Average	88.3	95.3	92.6	87.2
478	1	Milk and straight-grade flour bread	93.5	96.3	97.0	90.3
479	2	.....do	94.2	97.4	98.2	92.0
480	3	.....do	93.4	94.7	98.1	91.5
		Average	93.7	96.1	97.8	91.3
484	1	Milk and Graham flour bread	85.2	93.5	88.1	82.4
485	2	.....do	88.5	95.2	90.7	88.2
486	3	.....do	87.2	94.4	90.1	85.1
		Average	87.0	94.4	89.6	85.2

[a] Omitted from average.

TABLE 24.—*Digestibility of nutrients and availability of energy of bread alone.*

Experiment No.	Subject No.	Kind of food.	Protein.	Carbohydrates.	Energy.
		Experiments with Oregon wheat.			
			Per cent.	*Per cent.*	*Per cent.*
469	1	Entire-wheat flour bread	66.9	93.8	87.0
470	2	.....do	77.5	94.6	89.5
471	3	.....do	68.9	93.8	86.7
		Average	71.1	94.1	87.7
472	1	Straight-grade flour bread	85.6	98.0	94.8
473	2	.....do	89.4	98.9	96.3
474	3	.....do	79.8	97.8	94.0
		Average	84.9	98.2	95.0
475	1	Graham flour bread	60.6	90.1	80.7
476	2	.....do	65.3	90.9	83.5
477	3	.....do	[a]40.5	92.6	82.6
		Average	63.0	91.2	82.3
		Experiments with Oklahoma wheat.			
481	1	Entire-wheat flour bread	75.7	89.6	81.9
482	2	.....do	84.4	92.0	86.5
483	3	.....do	78.7	90.0	82.9
		Average	79.6	90.5	83.8
478	1	Straight-grade flour bread	90.2	96.7	90.7
479	2	.....do	91.9	98.2	93.3
480	3	.....do	90.6	98.1	92.2
		Average	90.9	97.7	92.1
484	1	Graham flour bread	74.1	85.6	76.1
485	2	.....do	82.2	89.1	86.1
486	3	.....do	75.6	87.4	79.6
		Average	77.3	87.4	80.6

[a] Omitted from average.

COMPARISON OF BREAD FROM THE THREE GRADES OF FLOUR FROM THE SAME LOT OF WHEAT.

In the experiments with Oregon wheat, the figures in Table 24 show striking differences in the digestion of protein of the same flour by the different subjects. Thus, subject No. 2 digested 65.3 per cent of the protein of Graham bread, whereas subject No. 3 digested only 40.5 per cent. The latter figure is considered abnormally low and is not included in the average. In the experiments with the entire-wheat bread, subject No. 1 digested 66.9 per cent of the protein, and subject No. 2 digested 77.5 per cent; and the variation was nearly as wide in the experiments with bread from straight-grade flour, ranging from 79.8 per cent with subject No. 3 to 89.4 per cent with subject No. 2. On the other hand, in the case of the carbohydrates and energy, the variations for the different subjects with the same flour were comparatively small. Notwithstanding the wide range in the digestibility of protein of the same flour by the different subjects, the results are in perfect accord in this respect, that each subject digested the nutrients of the straight-grade flour more thoroughly than those of

the entire-wheat, and the nutrients of the latter more thoroughly than those of the Graham flour. Likewise the energy of the straight-grade flour was more available than that of entire-wheat or Graham.

In the experiments with Oklahoma wheat, there were also appreciable differences in the digestibility of the protein of the entire-wheat flour by the different subjects, and the same in the case of the Graham flour. The results for the protein of the straight-grade flour were in close agreement. As was the case with the Oregon flours, the results with the different subjects on the same flour agreed quite closely in respect to the digestibility of carbohydrates and the availability of energy. Furthermore, with each subject the digestibility of the nutrients and the availability of the energy of the different flours was in the following order: Straight-grade, entire-wheat, and Graham.

In brief, then, the flours from both kinds of wheat give the same results, namely, the nutrients of the straight-grade flour are more digestible than those of the entire-wheat flour, and the latter are more digestible than those of the Graham flour.

This means that, when the three flours compared are ground from the same lot of wheat, in actual nutritive value the straight-grade flour stands first, entire-wheat flour next, and Graham flour last. This may be more clearly apparent when the data are summarized in the manner shown in the following table:

TABLE 25.—*Proportion of total and digestible nutrients and total and available energy in different grades of Oregon and Oklahoma flour as milled.*

Sample No.	Kind of flour.	Protein (N×6.25).		Carbohydrates.		Energy per gram.	
		Total.	Digestible.	Total.	Digestible.	Total.	Available.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*
271	Oregon Graham flour	8.97	5.65	79.48	72.49	3.990	3.284
272	Oregon entire-wheat flour	8.25	5.87	80.35	75.61	3.900	3.420
273	Oregon straight-grade flour	7.55	6.41	81.82	80.35	3.880	3.686
274	Oklahoma Graham flour	16.81	12.99	72.35	63.23	4.178	3.367
275	Oklahoma entire-wheat flour	16.63	13.24	73.05	66.11	4.159	3.485
276	Oklahoma straight-grade flour	15.06	13.69	73.57	71.88	4.040	3.721

In the case of the Oregon wheat, considering total protein, the Graham flour contained 8.97 per cent, the entire-wheat 8.25 per cent, and the straight-grade 7.55 per cent; but, considering digestible protein, the straight-grade flour contained 6.41 per cent, whereas the Graham flour contained only 5.65 per cent. Likewise the total energy per gram was 3.990 calories for Graham flour and 3.880 calories for straight-grade; but the available energy per gram was 3.686 calories for the straight-grade flour and only 3.284 calories for the Graham flour. In the case of the Oklahoma wheat also the proportions of total protein and energy were largest in the Graham and smallest in the straight-grade flour, whereas the proportions of digestible protein and available energy were largest in the straight-grade and smallest in the

Graham flour. That is, in the flours from both kinds of wheat the relative nutritive values of the three grades, as shown by digestible protein and available energy, were, first, straight-grade and, last, Graham.

In this respect the results obtained in these experiments are exactly in accord with those obtained in similar investigations with wheat from other localities. This means that from the same quantity of the three grades of flour from the same lot of wheat the body would actually obtain more protein and energy from the entire-wheat flour than from the Graham, and still more from the straight-grade flour than from the entire-wheat flour.

In general it may be said that the results obtained with the two sorts of wheat studied in the investigation here reported are in accord with those obtained in the earlier investigations of the series. This fact is a confirmation of the belief that the conclusions drawn regarding the nutritive value of different sorts of flour hold good for all varieties of wheat, provided the different flours are ground from the same sample.

COMPARISON OF BREAD FROM THE SAME GRADE OF FLOUR FROM THE TWO LOTS OF WHEAT.

Certain differences are noticeable in the digestibility of the nutrients and availability of the energy of the breads from similar grades of flour produced from the two lots of wheat. It will be observed that the percentage of digestible carbohydrates and available energy is larger, on the average, for each grade of flour from the Oregon wheat than for the same grade from the Oklahoma wheat, though the differences are not great. With the protein, on the other hand, the differences are larger and the conditions are reversed, the digestibility of the flours from the Oklahoma wheat being greater than that of the corresponding flours from the Oregon wheat. As previously noted, the flour from the Oregon wheat was comparatively low in protein, whereas that from the Oklahoma wheat was high.

In a former investigation[a] an attempt was made to determine the effect upon digestibility of adding wheat starch to a flour relatively rich in protein, in order to reduce the proportion of protein. In those experiments the difference between the percentage of protein in the normal flour and that in the same flour modified by the addition of starch was not so large as the difference between the protein content of the Oklahoma and that of the Oregon flour used in the present experiments. In the former experiments the digestibility of protein was lower in the flour with the increased starch content (i. e., reduced protein content) than in the normal flour. Similarly, in the present experiments, the protein was less digestible in the flour with

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 54.

the lower protein content, the differences in the present instance being even more pronounced than those in the earlier experiments. In both cases, then, the indications are that the widening of the ratio of protein to starch in the flour lowers the digestibility of the protein.

As mentioned before, the differences in digestibility of the carbohydrates of the same grade of flour from the two lots of wheat were small, being largest in the case of the entire-wheat and Graham flours. In the case of the straight-grade flours 98.2 per cent of the carbohydrates from the Oregon wheat and 97.7 per cent from the Oklahoma wheat were digested. Since the carbohydrates of wheat flour are composed largely of starch, it is evident that wheat starch is a highly digestible nutrient, and more thoroughly digested in the form of straight-grade than in the other flours. The average difference in the digestibility of the carbohydrates of the breads made from the Graham and straight-grade flours amounts to 8.7 per cent in favor of the straight-grade flour.

UNDIGESTED STARCH IN FECES.

In former reports it was pointed out that the large particles observed in the fecal matter from the Graham and entire-wheat flours contained unaltered wheat-starch granules, which had escaped complete digestion. In the present digestion experiments also, microscopic studies showed the presence of unaltered starch grains in the feces from the Graham and entire-wheat flours.

EXPERIMENTS WITH BREAD FROM "BRAN FLOUR."

As pointed out in the preceding experiments in the present bulletin and in similar experiments previously reported, the Graham flour which contains the whole of the wheat kernel, including the bran, and is more coarsely ground than entire-wheat or standard patent flours, is less digestible than either of these two grades. The cause of this difference has sometimes been attributed to the coarseness of the branny particles. In order to determine what influence bran in a fine state of division would have upon the completeness of digestion, three experiments were made with straight-grade flour to which very finely ground bran was added. For convenience this material has been designated "bran flour."

This bran flour was prepared from milling products of Oklahoma wheat, described on pages 12 and 13. A quantity of the bran (No. 413) was ground in a burr mill and then in a Maerker mill until it was very fine. Some of the ground bran was then mixed with straight-grade flour (No. 276), the quantity of bran in the mixture (No. 415) being 14 per cent of the total, which was about the proportion of bran removed in milling. Bread was made from this modified flour in the same way

as from the ordinary flours (see p. 18), and was used in digestion experiments with the same subjects as in the preceding experiments. One experiment was made with each subject. The data of the experiments are given in Tables 26 to 28, which follow.

DIGESTION EXPERIMENT NO. 487.

Kind of food.—Milk, and bread made from bran flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 182 pounds; at the close 179.5 pounds.

Duration.—Three days, with nine meals, beginning with breakfast May 23, 1903.

TABLE 26.—*Results of digestion experiment No. 487.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
379	Bread	2,043.0	194.1	17.2	930.6	18.6	5,105
380	Milk	8,854.6	309.0	436.5	318.8	91.2	7,084
	Total	.....	503.1	453.7	1,249.4	109.8	12,189
393	Feces (water-free)	175.0	41.8	23.4	71.8	38.0	795
	Estimated feces from food other than bread	.....	9.3	21.8	6.3	.....	296
	Estimated feces from bread	.....	32.5	.....	65.5	.....	499
	Total amount digested	.....	461.3	430.3	1,177.6	71.8	11,394
	Estimated digestible nutrients in bread	.....	161.6	.....	865.1	.....	4,606
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	91.7	94.9	94.3	65.4	(93.5)
	Estimated coefficients of digestibility of bread alone	.....	83.2	.....	93.0	.....	(90.2)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	88.8
	In bread alone	.....	.....	.....	.....	.....	86.3

During this experiment the subject eliminated 4,473 grams urine, containing 65.75 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 26.83 grams; outgo in urine 21.92 grams; and in feces 2.23 grams; implying a gain of 2.68 grams nitrogen, corresponding to 16.8 grams protein.

DIGESTION EXPERIMENT NO. 488.

Kind of food.—Milk, and bread made from bran flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 155 pounds; at the close 155.5 pounds.

Duration.—Three days, with nine meals, beginning with breakfast May 23, 1903.

TABLE 27.—*Results of digestion experiment No. 488.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
379	Bread	1,611.0	153.0	13.5	733.8	14.6	4,026
380	Milk	5,220.0	182.2	257.4	187.9	53.8	4,176
	Total	.....	335.2	270.9	921.7	68.4	8,202
394	Feces (water-free)	129.5	29.3	12.9	56.6	30.7	544
	Estimated feces from food other than bread	.....	5.5	12.9	3.7	.....	172
	Estimated feces from bread	.....	23.8	.....	52.9	.....	372
	Total amount digested	.....	305.9	258.0	865.1	37.7	7,658
	Estimated digestible nutrients in bread	.....	129.2	.....	680.9	.....	3,654
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	91.3	95.2	93.9	55.2	(93.4)
	Estimated coefficients of digestibility of bread alone	.....	84.4	.....	92.8	.....	(90.8)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	88.7
	In bread alone	.....	.....	.....	.....	.....	86.8

During this experiment the subject eliminated 3,016 grams urine, containing 62.73 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 17.88 grams; outgo in urine 20.91 grams; and in feces 1.56 grams; implying a loss of 4.59 grams nitrogen, corresponding to 28.7 grams protein.

DIGESTION EXPERIMENT NO. 489.

Kind of food.—Milk, and bread made from bran flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 158.5 pounds; at the close 156 pounds.

Duration.—Three days, with nine meals, beginning with breakfast May 23, 1903.

TABLE 28.—*Results of digestion experiment No. 489.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
379	Bread	1,558.0	148.0	13.1	709.7	14.2	3,893
380	Milk	5,660.0	197.5	279.0	203.8	58.3	4,528
	Total	.....	345.5	292.1	913.5	72.5	8,421
395	Feces (water-free)	93.3	20.8	6.7	44.9	20.9	460
	Estimated feces from food other than bread	.....	5.9	14.0	4.1	.....	224
	Estimated feces from bread	.....	14.9	.....	40.8	.....	236
	Total amount digested	.....	324.7	285.4	868.6	51.6	7,961
	Estimated digestible nutrients in bread	.....	133.1	.....	668.9	.....	3,657

TABLE 28.—*Results of digestion experiment No. 489*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 94.0	*Per cent.* 97.7	*Per cent.* 95.1	*Per cent.* 71.1	*Per cent.* (94.5)
	Estimated coefficients of digestibility of bread alone		90.0		94.3		(93.9)
	Proportion of energy actually available to the body:						
	In total food						89.7
	In bread alone						89.7

During the experiment the subject eliminated 3,023 grams urine, containing 47.46 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 18.43 grams; outgo in urine 15.82 grams; and in feces 1.11 grams; implying a gain of 1.50 grams nitrogen, corresponding to 9.4 grams protein.

SUMMARY OF RESULTS OBTAINED WITH BREAD FROM BRAN FLOUR.

The results of the experiments with bread from bran flour are summarized in Table 29. For purposes of comparison the table also includes the average of experiments with bread made from the same flour without the bran.

TABLE 29.—*Digestibility of nutrients and availability of energy of bread from straight-grade flour with and without bran.*

Experiment No.	Subject No.	Kind of bread.	Protein.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*
487	1	Bread from straight-grade flour with bran added	83.2	93.0	86.3
488	2	.....do	84.4	92.8	86.8
489	3	.....do	90.0	94.3	89.7
		Average	85.9	93.4	87.6
478	1	Bread from straight-grade flour without bran	90.2	96.7	90.7
479	2	.....do	91.9	98.2	93.3
480	3	.....do	90.6	98.1	92.2
		Average	90.9	97.7	92.1

In the experiments with the straight-grade flour without the bran the results with the three subjects were in very close agreement. In the experiments with the same flour plus bran the results for carbohydrates and energy agreed fairly well, but subject No. 3 digested more of the protein than either of the other subjects, the results for these two being close. Subject No. 3 digested practically the same proportion of the protein from the flour with the bran as from that without it, but with the other subjects the protein of the bran flour was noticeably less digestible than that of the straight-grade flour. With all three subjects the digestibility of the carbohydrates and the availability of the energy were lower for the bran flour than for the straight-grade flour.

Considering the averages of the experiments with both kinds of flour, the digestibility of the bread from the flour with the bran was, for protein 85.9 per cent and for carbohydrates 93.4 per cent, whereas that of the bread from the same flour without the bran was, for protein 90.9 per cent and for carbohydrates 97.7 per cent. The inference from these results is that the addition of the finely ground bran decreased the digestibility of the product.

Though the bran flour contained a larger percentage of protein than the flour without the bran, in consequence of its lower digestibility the nutritive value of the former was actually less, as will be apparent from a comparison of the data summarized in the following table, showing the percentages of total and digestible nutrients and the total and available energy per gram in both kinds of flour:

TABLE 30.—*Comparison of total and digestible nutrients and total and available energy in the same flour with and without bran.*

Sample No.	Kind of flour.	Protein (N×6.25).		Carbohydrates.		Energy per gram.	
		Total.	Digestible.	Total.	Digestible.	Total.	Available.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*
415	Straight grade flour with bran added	15.35	13.19	72.23	67.46	3.876	3.395
276	Straight grade flour without bran	15.06	13.69	73.57	71.88	4.040	3.721

There was a larger percentage of total protein and a smaller percentage of total carbohydrates in the flour with the bran than in that without it; but comparing the digestible nutrients it will be observed that what little was gained in total amount added by including the finely ground bran was more than lost in the decreased digestibility due to the addition of the bran, the proportions of digestible nutrients and available energy being larger in the flour without the bran added. This means that from the same amounts of both kinds of flour the body would actually derive more nutrients and energy from the flour without the bran in spite of the fact that the amount of protein is larger in the flour with the bran added.

It is interesting to compare the average values for the digestibility of Graham and entire-wheat flours, that is, flours normally containing more or less coarse bran, with the average results obtained in digestion experiments with straight-grade patent flour to which finely ground bran was added. Such a comparison is made in the following table, which also shows the digestibility of straight-grade flour:

TABLE 31.—*Nutrients digested from bread from different kinds of flour.*

Kind of flour.	Protein.	Carbohydrates.
	Per cent.	*Per cent.*
Graham flour	77.3	87.4
Entire-wheat flour	79.6	90.5
Straight-grade flour with bran added	85.9	93.4
Straight-grade flour	90.9	97.7

As has been explained, the Graham flour contained the whole of the wheat kernel and was practically wheat meal, and the entire-wheat flour contained all of the kernel except the tough outer skin and was somewhat more finely ground than the Graham. The bran flour consisted of straight-grade flour that contained neither bran nor germ, to which was added the same amount of bran that had been removed in milling, the bran having been specially ground until it was about as fine as it seemed possible to make it. The entire-wheat flour was somewhat more digestible than the Graham, and the bran flour was more digestible than the entire-wheat, but less so than the straight-grade flour. It would seem from these data that the finer grinding of the bran increased its digestibility to a certain extent; but apparently its defective digestibility is not entirely due to imperfect grinding, because even when finely ground, flour containing it was still less digestible than the flour without the bran, which indicates that bran has some inherent property of resisting the digestive juices. That is to say, apparently, when bran was in a fine state of division, as in these experiments, it not only failed to digest completely itself, but it also prevented the complete digestion of the white flour with which it was associated.

The question has been studied by other investigators, and, in general, it may be said that in the majority of cases when the experimental conditions were uniform the results obtained are in accord with those reported here. No attempt is made here to refer to all of this work, though the reports of all such experiments which have been found are included in an unpublished bibliography of bread and related foods prepared in connection with the nutrition investigations of the Department of Agriculture and referred to in a previous publication.[a]

In a study of the comparative nutritive value of homemade and bakers' bread, Alice M. Fitz[b] found that a 10-cent loaf of bakers' whole-wheat bread was a little heavier, but contained a smaller percentage of protein and energy, than 10-cent loaves of three sorts of bakers' white bread. With bread prepared at home from uniform quantities and under uniform conditions less pronounced differences were noted in the composition and energy value of whole-wheat and ordinary breads.

Hutchison[c] gives results obtained by Goodfellow, showing "that the waste in milk is greater by 3 per cent when given along with whole-meal bread than when taken alone. This, as we have seen, is the very reverse of the effect exercised by ordinary bread."

Experiments by Romberg[d] have shown that a mixture of finely

[a] U. S. Dept. Agr., Rpt. Director Office Experiment Stations 1902, p. 267.
[b] Amer. Kitchen Mag., 17 (1902), p. 139.
[c] Food and the Principles of Dietetics. London: Edward Arnold, 1901, p. 206.
[d] Arch. Hyg., 28 (1897), p. 244.

ground rye bran and flour is not so completely absorbed as the flour without the bran. A number of digestion experiments were made by him to determine the comparative digestibility of the different kinds and grades of rye flour. The experiments, which are of especial interest in connection with a discussion of the effect of the presence of bran in the flour on the digestibility of bread, are summarized in the table below. The data as originally published showed the percentage amounts which escaped digestion, but in quoting the results they have been recalculated to show the coefficients of digestibility, so that they may be more readily compared with those reported in this bulletin.

TABLE 32.—*Coefficients of digestibility of different kinds of rye bread.*

Kind of flour used for making bread.	Dry matter.	Protein.	Carbohydrates.
	Per cent.	*Per cent.*	*Per cent.*
Fine light-colored rye flour	95.85	77.93	98.34
Fine rye flour containing a little bran	92.49	71.37	95.85
Fine dark-colored rye flour containing considerable bran	86.36	64.49	91.92
Rye graham flour mixed with a little fine flour	79.93	59.97	85.60
Rye flour ground from entire grain	94.22	67.98	97.59

From these tests and others made with the different rye milling products the conclusion was drawn that adding the bran, even if finely ground, diminished digestibility and that bran can not be so prepared by grinding that it is suited for human food.

Pannwitz,[a] in a study of the nutritive value of different sorts of army bread, also reported at length by Plagge and Lebbin,[b] took into account the effect of the presence of different proportions of bran on digestibility. In these experiments the diet consisted of bread alone. The following table summarizes the principal results and, as before, the data have been recalculated to show the coefficients of digestibility instead of the amounts which escaped digestion:

TABLE 33.—*Coefficients of digestibility of different sorts of bread.*

Kind of flour used for making bread.	Dry matter.	Protein.
	Per cent.	*Per cent.*
Decorticated rye flour with 15 per cent bran removed	86.80	56.65
Coarse decorticated rye flour with 7.5 per cent bran removed	84.12	43.35
Coarse decorticated rye flour with 15 per cent bran removed	87.76	58.56
Finely ground decorticated rye flour with 10.84 per cent bran removed	87.76	66.38
Finely ground undecorticated rye flour with 12.68 per cent bran removed	87.39	60.88
Finely ground undecorticated rye flour with 25 per cent bran removed	90.51	66.25
Fine wheat flour with 30 per cent bran removed	93.93	81.31
Finely ground bran	57.65	43.68
Coarsely ground rye, no bran removed—"pumpernickel"	84.34	47.96
Entire-rye bread made from crushed grain without previous grinding	78.59	49.65

The conclusion was reached that the value of flour depended upon the amount of bran removed, and that bran, even if finely ground, was not suitable for human food. In the author's opinion, decortication before grinding is not necessary provided 15 to 25 per cent of the bran

[a] Inaug. Diss., Univ. Berlin, 1898. [b] Veröffentl. Mil. Sanitätsw., 1897, No. 12.

present is removed in milling; and, furthermore, unless 15 per cent of the bran is removed, the decorticated grain, either finely or coarsely ground, gives a bread of inferior digestibility.

In a study of the relation of decortication and grinding to digestibility Lehmann[a] reports data which have to do with the effect of bran on the digestibility of bread. The data are summarized in Table 34.

TABLE 34.—*Coefficients of digestibility of different sorts of bread.*

Kind of flour used for making bread.	Dry matter.	Protein.
	Per cent.	*Per cent.*
Coarsely ground decorticated rye flour, Steinmetz process, 94 per cent of the grain	85.73	45.30
Finely ground rye flour, old process, 70 per cent of the grain	89.25	44.25
Rather coarsely ground decorticated rye flour, Steinmetz process, 82 per cent of the grain	87.71	54.08
Finely ground rye flour, old process, 62 per cent of the grain	88.66	51.70
Finely ground commercial rye flour, 75 per cent of the grain	87.52	53.37

In the author's opinion the flour specially ground by the Steinmetz process, which contained not less than 15 per cent of bran, was about as digestible as ordinary rye-flour bread when it forms a part of a mixed diet, and, in general, he concludes that there was no marked and regular difference in the digestibility of flour from which 18 to 38 per cent of the bran was removed.

Lehmann's conclusions are not in accord with the others cited, and it seems fair to say that the consensus of opinion is unfavorable to bran as a constituent of flour.

EXPERIMENTS WITH BREAD FROM "GERM FLOUR."

Experiments similar to those with bran were also made to determine the influence of the addition of germ to white flour. A sample of germ (No. 414, obtained in milling flour No. 276) containing 29.88 per cent of protein and 11.23 per cent fat was ground in the same manner as the bran. A mixture, designated as "germ flour," was then made, containing 93 per cent of Oklahoma straight-grade flour (No. 276) and 7 per cent of the finely ground germ, the germ being added in about the same proportion as is removed during the milling process. Bread was made from this mixture as previously described, and a digestion experiment with each of the three subjects of the preceding experiments was conducted in the usual manner. The data of these experiments are given in Tables 35 to 37 following.

DIGESTION EXPERIMENT NO. 490.

Kind of food.—Milk, and bread made from germ flour.

Subject.—Man No. 1. Conditions as in experiment No. 469.

Weight.—At the beginning of the experiment 180 pounds; at the close 178 pounds.

[a] Arch. Hyg., 45 (1902), p. 177.

Duration.—Three days, with nine meals, beginning with breakfast May 28, 1903.

TABLE 35.—*Results of digestion experiment No. 490.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
396	Bread	2,395.0	265.1	27.1	1,176.4	16.3	6,689
397	Milk	8,895.0	271.3	386.9	446.5	66.7	6,671
	Total		536.4	414.0	1,622.9	83.0	13,360
410	Feces (water-free)	135.3	41.0	14.6	43.9	35.8	659
	Estimated feces from food other than bread		8.2	19.4	8.9		312
	Estimated feces from bread		32.8		35.0		347
	Total amount digested		495.4	399.4	1,579.0	47.2	12,701
	Estimated digestible nutrients in bread		232.3		1,141.4		6,342
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		92.4	96.5	97.3	56.9	(95.1)
	Estimated coefficients of digestibility of bread alone		87.6		97.0		(94.8)
	Proportion of energy actually available to the body:						
	In total food						90.4
	In bread alone						90.5

During this experiment the subject eliminated 4,913 grams urine, containing 79.59 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 28.61 grams; outgo in urine 26.53 grams; and in feces 2.18 grams; implying a loss of 0.10 gram nitrogen, corresponding to 0.6 gram protein.

DIGESTION EXPERIMENT NO. 491.

Kind of food.—Milk, and bread made from germ flour.

Subject.—Man No. 2. Conditions as in experiment No. 470.

Weight.—At the beginning of the experiment 155 pounds; at the close 154 pounds.

Duration.—Three days, with nine meals, beginning with breakfast May 28, 1903.

TABLE 36.—*Results of digestion experiment No. 491.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
396	Bread	2,139.0	236.8	24.2	1,050.7	14.6	5,974
397	Milk	6,550.0	199.8	284.9	328.8	49.1	4,913
	Total		436.6	309.1	1,379.5	63.7	10,887
411	Feces (water-free)	93.0	27.1	9.7	28.9	27.3	403
	Estimated feces from food other than bread		6.0	14.3	6.5		213
	Estimated feces from bread		21.1		22.4		190
	Total amount digested		409.5	299.4	1,350.6	36.4	10,484
	Estimated digestible nutrients in bread		215.7		1,028.3		5,784

TABLE 36.—*Results of digestion experiment No. 491*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 93.8	*Per cent.* 96.9	*Per cent.* 97.9	*Per cent.* 57.2	*Per cent.* (96.3)
	Estimated coefficients of digestibility of bread alone		91.1		97.9		(96.8)
	Proportion of energy actually available to the body:						
	In total food						91.6
	In bread alone						92.3

During this experiment the subject eliminated 2,598 grams urine, containing 47.02 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 23.28 grams; outgo in urine 15.67 grams; and in feces 1.45 grams; implying a gain of 6.16 grams nitrogen, corresponding to 38.5 grams protein.

DIGESTION EXPERIMENT NO. 492.

Kind of food.—Milk, and bread made from germ flour.

Subject.—Man No. 3. Conditions as in experiment No. 471.

Weight.—At the beginning of the experiment 152 pounds; at the close 152 pounds.

Duration.—Three days, with nine meals, beginning with breakfast May 28, 1903.

TABLE 37.—*Results of digestion experiment No. 492.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
396	Bread	1,750.0	193.7	19.8	859.6	11.9	4,888
397	Milk	5,600.0	170.8	243.6	281.1	42.0	4,200
	Total		364.5	263.4	1,140.7	53.9	9,088
412	Feces (water-free)	79.0	22.1	12.8	23.9	20.2	357
	Estimated feces from food other than bread		5.1	12.2	5.6		171
	Estimated feces from bread		17.0		18.3		186
	Total amount digested		342.4	250.6	1,116.8	33.7	8,731
	Estimated digestible nutrients in bread		176.7		841.3		4,702
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		94.0	95.1	97.9	62.5	(96.1)
	Estimated coefficients of digestibility of bread alone		91.3		97.9		(96.2)
	Proportion of energy actually available to the body:						
	In total food						91.4
	In bread alone						91.7

During this experiment the subject eliminated 3,542 grams urine, containing 51.71 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 19.44 grams; outgo in urine 17.24 grams; and in feces 1.18 grams; implying a gain of 1.02 grams nitrogen, corresponding to 6.4 grams protein.

SUMMARY OF RESULTS OBTAINED WITH BREAD FROM GERM FLOUR.

The results of the experiments with bread made from the mixture of straight-grade flour and ground germ are summarized in the following table. For comparison the results of experiments with bread made from the same flour without the germ are also included.

TABLE 38.—*Digestibility of nutrients and availability of energy of bread from straight-grade flour with and without germ.*

Experiment No.	Subject No.	Kind of bread.	Protein.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*
490	1	Bread from flour with germ added	87.6	97.0	90.5
491	2	.....do	91.1	97.9	92.3
492	3	.....do	91.3	97.9	91.7
		Average	90.0	97.6	91.5
478	1	Bread from flour without germ	90.2	96.7	90.7
479	2	.....do	91.9	98.2	93.3
480	3	.....do	90.6	98.1	92.2
		Average	90.9	97.7	92.1

Subjects Nos. 1 and 2 digested slightly less and subject No. 3 slightly more protein from the flour with the germ than from that without it, the average from the latter flour being practically 1 per cent higher. The average for carbohydrates was the same for both kinds of flour, and the availability of energy was a trifle higher in the flour without the germ, but on the whole the differences in results were so small as to be negligible. Apparently, then, the presence of the finely ground germ exerts no appreciable influence upon the digestibility of the flour.

The relative nutritive value of the flour with and without the germ is illustrated by the data here summarized.

TABLE 39.—*Comparison of total and digestible nutrients and total and available energy in the same flour with and without germ.*

Sample No.	Kind of flour.	Protein (N×6.25).		Carbohydrates.		Energy per gram.	
		Total.	Digestible.	Total.	Digestible.	Total.	Available.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*	*Calories.*
416	Straight-grade flour with germ added	16.30	14.67	71.63	69.91	3.962	3.625
276	Straight-grade flour without germ	15.06	13.69	73.57	71.88	4.040	3.721

As will be seen from the data in Table 1, the proportion of protein in the germ is much larger than that in any other milling product from the same wheat, being in the sample analyzed nearly twice as

large as in the straight-grade flour. Accordingly, the mixture of germ and straight-grade flour containing only 7 per cent of the former had an appreciably larger percentage of total protein than the straight-grade flour alone, 16.30 as compared with 15.06 per cent. Since the digestibility of the protein in the mixture was nearly the same as that in the flour without the germ, the percentage of digestible protein was also larger in the former, being 14.67 as compared with 13.69 per cent. The proportions of total and digestible carbohydrates, on the other hand, were both larger in the straight-grade flour alone, and their excess was sufficient to make the total and available energy per gram also larger in the flour without the germ. On the whole, then, the total nutritive value of the flour containing the germ is no greater than that without it.

Under certain circumstances, for example, where bread forms a considerable part of the total diet, a flour with a large protein content and a smaller starch content might be advantageous, because the proportion of starch to protein in flour is so large that a deficiency of protein might be characteristic of such a diet. The addition of the finely ground germ would then be an advantage, because, as shown above, the germ is rich in protein, and appreciably increases the protein content of the mixture; and the digestibility of the mixture is practically equal to that of the flour without the germ.

The particular disadvantage in including the germ is the effect it has upon the quality of the flour. The ground germ is easily fermentable and becomes rancid, and when present the flour does not keep well. Furthermore, it has been shown that the proteids of wheat germ are decidedly different in character and composition from wheat gluten, and that the agglutinating properties of the germ are poor.[a] A loaf from flour containing the germ, though sweeter in taste, is somewhat smaller in size and less attractive in appearance than one from straight-grade flour without the germ. From a practical standpoint, however, this latter feature is of much less importance than the poor keeping quality of the flour.

THE COMPARATIVE PECUNIARY VALUE OF GRAHAM, ENTIRE-WHEAT, AND STRAIGHT-GRADE FLOUR.

While the composition, digestibility, and palatability of a food are important factors in determining its value, the cost or comparative pecuniary value also requires consideration. Graham and entire-wheat flours are usually sold at a higher price than white or ordinary bread flour. Since the white (straight-grade) flour contains somewhat more digestible nutrients than either Graham or entire-wheat flours, it will readily be seen that for a given sum of money white flour would

[a] Minnesota Station Bul. 63, p. 527.

furnish the largest amount of digestible nutrients and available energy. At the time of this investigation flour was selling in the principal markets of the Northwestern States at a cost not exceeding $4.50 per barrel, while entire-wheat and Graham flour sold in small packages at the rate of $6 to $8 per barrel. In some cases much higher prices are charged for entire-wheat flour and similar preparations, as noted in studies carried on at the Maine Experiment Station.[a]

In the following table the comparative amounts of digestible nutrients which, at the prices given above, can be procured for 10 cents in the three types of flour milled from the Oklahoma wheat are given:

TABLE 40.—*Comparative amounts of digestible nutrients obtained for 10 cents in different grades of flour.*

Kind of flour.	Price per pound.	Total quantity obtainable.	Protein obtainable.	Carbohydrates obtainable.
	Cents.	*Pounds.*	*Pounds.*	*Pounds.*
White flour	2.25	4.4	0.60	3.16
Entire-wheat flour	3.00	3.3	.44	2.18
Graham flour	3.00	3.3	.43	2.09

At the prices given 10 cents will purchase 4.4 pounds of white and only 3.3 pounds of entire-wheat or Graham flour. The 4.4 pounds of white flour contain 1.24 pounds more of available protein and carbohydrates than 3.3 pounds of Graham costing the same amount of money. The 4.4 pounds of white flour contain 1.14 pounds more digestible protein and carbohydrates than the 3.3 pounds of entire-wheat flour costing the same amount of money. From a pecuniary point of view it is evident that the white flour is much the cheaper.

INCOME AND OUTGO OF NITROGEN.

Table 41 summarizes data regarding the income of nitrogen in the food and the outgo in the feces and urine, as well as the gain or loss by the body in the digestion experiments with the different sorts of bread reported in the preceding pages. The figures in each case represent the average amounts per day.

[a] Maine Station Rpt. 1899, pp. 92–106.

TABLE 41.—*Average daily income and outgo of nitrogen in digestion experiments Nos. 469–492.*

Experiment No.	Subject No.	Kind of food.	Nitrogen.			
			In food.	In urine.	In feces.	Gain (+) or loss (−).
		Oregon wheat.				
			Grams.	*Grams.*	*Grams.*	*Grams.*
469	1	Entire-wheat flour bread with milk	17.87	15.74	1.81	+0.32
470	2	.....do	17.56	13.16	1.69	+2.71
471	3	.....do	11.81	11.95	1.52	−1.66
472	1	Straight-grade flour bread with milk	16.34	17.91	1.12	−2.69
473	2	.....do	16.10	12.27	.98	+2.85
474	3	.....do	12.66	12.93	1.29	−1.56
475	1	Graham flour bread with milk	14.19	14.65	3.48	−3.94
476	2	.....do	12.28	12.35	2.49	−2.56
477	3	.....do	8.35	12.40	2.41	−6.46
		Oklahoma wheat.				
478	1	Straight-grade flour bread with milk	27.90	27.79	1.81	−1.70
479	2	.....do	19.55	19.94	1.14	−1.53
480	3	.....do	18.40	15.89	1.21	+1.30
481	1	Entire-wheat flour bread with milk	28.53	24.15	4.10	+ .28
482	2	.....do	19.26	16.82	1.89	+ .55
483	3	.....do	16.72	15.04	1.85	− .17
484	1	Graham flour bread with milk	29.93	26.87	4.44	−1.38
485	2	.....do	19.89	16.38	2.28	+1.23
486	3	.....do	15.41	14.50	1.98	−1.07
		Bran flour.				
487	1	Bran flour bread with milk	26.83	21.92	2.23	+2.68
488	2	.....do	17.88	20.91	1.56	−4.59
489	3	.....do	18.43	15.82	1.11	+1.50
		Germ flour.				
490	1	Germ flour bread with milk	28.61	26.53	2.18	− .10
491	2	.....do	23.28	15.67	1.45	+6.16
492	3	.....do	19.44	17.24	1.18	+1.02

The amount of nitrogen taken per day varied within rather wide limits, and it is noticeable that subject No. 3, in each series of tests, received considerably less nitrogen than the other two subjects, owing to the fact that he ate smaller amounts of food.

In experiments of a few days' duration it is not absolutely certain that the nitrogen of the urine represents that of the diet, though it seems probable that such is the case, as is indicated by the fact that marked changes in the nitrogen consumed are quickly followed by corresponding changes in the amounts excreted in the urine. In 11 of the experiments there was a gain of nitrogen and in 13 a loss. However, too much importance should not be attributed to these gains and losses, as the experimental periods were short and it is probable that in all cases nitrogen equilibrium would have been reached with the amounts consumed if the period had been longer. It is noticeable that on an average the feces from the coarser breads contained a larger proportion of the nitrogen consumed than was the case with the bread from straight-grade flour, a fact which has been brought out in referring to the lower coefficients of digestibility of the breads from the coarser flours. In general, no differences in the gains or losses of nitrogen were observed which could be attributed to the consumption of breads from different grades of flour.

GENERAL SUMMARY OF RESULTS AND CONCLUSIONS OF EXPERIMENTS WITH BREAD.

In eighteen digestion experiments with men it was found that white (straight-grade) flour was more completely digested than either Graham or entire-wheat flour, and yielded a larger amount of digestible nutrients and available energy. While Graham and entire-wheat flours contain more total protein and fat and have a higher heat of combustion, they actually yield to the body, because of their lower digestibility, smaller percentages of digestible nutrients and available energy than the straight-grade flour.

The same general differences in digestibility of the three grades of flour have been noted in experiments with hard northwestern spring wheats grown in Minnesota and Dakota, hard winter wheat grown in Oklahoma, and soft winter wheats grown in Michigan, Indiana, and Oregon. In fifty-four digestion trials with both hard spring wheats and soft winter wheats in which six separate samples of wheat have been milled so as to produce the three types of flour—Graham, entire-wheat, and straight-grade—uniform results have been secured, and in all of the comparative trials the largest amounts of available nutrients and energy have been secured from the white flour.

In the three digestion trials in which finely pulverized bran was added to white flour in the same proportion as is removed in milling, it was found that the addition of the bran lowered the digestibility of the flour so that a smaller amount of digestible nutrients and available energy was obtained from the bran flour than from the white flour with which the bran was mixed. The flour containing finely pulverized bran was more digestible than the coarsely granulated Graham flour, but less digestible than the white flour. When bran was finely pulverized it failed to digest as completely as the white flour and, therefore, the addition of the bran lowered the food value of the flour.

In three digestion trials in which finely pulverized wheat germ was added to white flour in the same proportion as is removed in milling, it was found that the addition of the germ did not materially change the digestibility of the flour, and that the amount of total digestible nutrients and available energy in the germ flour and the white flour was about the same. There was no material gain in total digestible nutrients by the addition of the germ to the white flour. The germ flour produced a smaller sized, sweeter, but less porous loaf than the white flour. Because of its fermentable character wheat germ is excluded from white flour.

As to pecuniary value, a larger amount of available nutrients and energy can be procured at the usual prices for a given sum of money in the form of white, that is, straight-grade, flour than of any other flour. White flour contains the largest amount of available nutrients, and is not only the most digestible, but at present average market prices is

also the cheapest kind of flour. It should not be inferred, however, that the use of entire-wheat and Graham flour is to be discouraged. All the flours are very nutritious and economical foods, and experience has shown that they are wholesome as well. The differences in the amounts of total nutrients furnished the body by the various grades of flour are comparatively slight, all grades being quite thoroughly digested.

In discussing the nutritive value of the breads made from the three kinds of flour, the quite noticeable effect of the breads upon the subjects is of interest. In the experiments reported all the subjects expressed a preference for the white bread. The Graham bread, when it furnished the bulk of the ration for four days, produced a little discomfort, suggesting a slight irritation of the digestive tract. The ration of white bread and milk was less bulky in character and gave better results as to satiety and particularly as to ease of digestion. It should be borne in mind, however, that the tendency of the coarser flours to increase the peristaltic action of the intestines is often of undoubted value, particularly to persons of sedentary habit, and that their use as a laxative is in many cases extremely beneficial.

The use of different grades of flour for bread making is a convenient means of increasing the variety of the diet. Because of varying requirements no general rule can be laid down in the matter, and the extent to which the various grades of flour should be used must be determined largely by the individual himself.

In this investigation the comparative digestibility of the phosphates and other mineral constituents was not determined, nor were the quantities consumed and the amounts and proportions excreted in the urine and feces studied. As yet entirely satisfactory methods have not been generally adopted for determining the digestibility of mineral constituents, and consequently there is a lack of definite knowledge concerning body requirements and the changes which are involved in the metabolism of the ash constituents of the diet. Considerable work along these lines is now being carried on by a number of investigators in France and elsewhere in Europe, and in the United States studies of the forms in which ash constituents, especially phosphorus, occur in food products, methods of estimating phosphorus, sulphur, and other ash constituents in food and excretory products, and various problems concerning the functions of these elements are being taken up in connection with the nutrition investigations of this Office and by experiment station workers and other investigators. It is believed that this work may be more appropriately summarized when the investigations now in progress have been continued for a longer time.

THE DIGESTIBILITY AND NUTRITIVE VALUE OF MACARONI.

INTRODUCTION.

Macaroni and similar foods, grouped together under the name of Italian pastes, are commonly said to be of Italian origin, but as pointed out in a recent journal[a] there is reason for believing that they were introduced into Sicily and Calabria by the early Greek settlers, and that the invention of these food products is to be ascribed to the Greeks. There are undoubtedly grounds for this statement, yet it should be remembered that similar food products have been known since early times in China and Japan, where they are still manufactured in large quantities.

Italian pastes are usually made from durum, or macaroni, wheat; that is, varieties which are of a glutinous character. The wheat is ground less finely than for ordinary flour-making purposes, the product being a coarse granular middlings known as semolina. In making macaroni this semolina is made into a stiff dough, kneaded and then pressed into tubes and dried. Though prepared for the table in a number of ways, the first treatment usually consists in parboiling the dried macaroni twenty to thirty minutes.

In connection with investigations carried on by the Bureau of Plant Industry of this Department regarding durum wheat, information is given regarding the process of manufacture of macaroni and related topics in a recent bulletin,[b] and also in earlier publications the character of such wheat, the relative value of different varieties, and other questions are considered. At the South Dakota Experiment Station[c] the value of durum wheat flour for making bread, cake, and similar foods has been studied, and tests on the milling of this wheat and the manufacture of macaroni have also been made.

The composition of macaroni and similar Italian pastes has often been determined by analysis, some of the work of this character having been carried on by experiment station investigators or those connected with the nutrition investigations of this Department. Rubner,[d] Jacoangeli and Bonanni,[e] Cappelletti,[f] and perhaps other investigators

[a] Home Sci. Mag., 20 (1903–4), p. 271.
[b] U. S. Dept. Agr., Bureau of Plant Industry Bul. 70.
[c] South Dakota Station Buls. 77 and 82.
[d] Ztschr. Biol., 15 (1879), p. 115.
[e] Bol. Not. Agr., 19 (1897), II, p. 434.
[f] Ztschr. Untersuch. Nahr. u. Genussmtl., 1 (1898), p. 384.

have studied the composition of macaroni and similar goods, but the amount of available information on this subject is not large.

In order to determine the nutritive value of macaroni made from American wheat, two series of experiments were undertaken which included the milling of the wheat, the preparation of the macaroni, and the determinations of its nutritive value when eaten by healthy young men who had a fair amount of muscular exercise. The wheat used in the series of experiments made in 1904 was grown at the North Dakota Experiment Station, and that used in the experiments made in 1905 was obtained at the North Dakota Substation, located at Edgeley. In both series the wheat was milled in the new experimental roller mill (Pl. IV) at the Minnesota Experiment Station and the semolina manufactured into macaroni by the Minnesota Macaroni Company, of St. Paul.

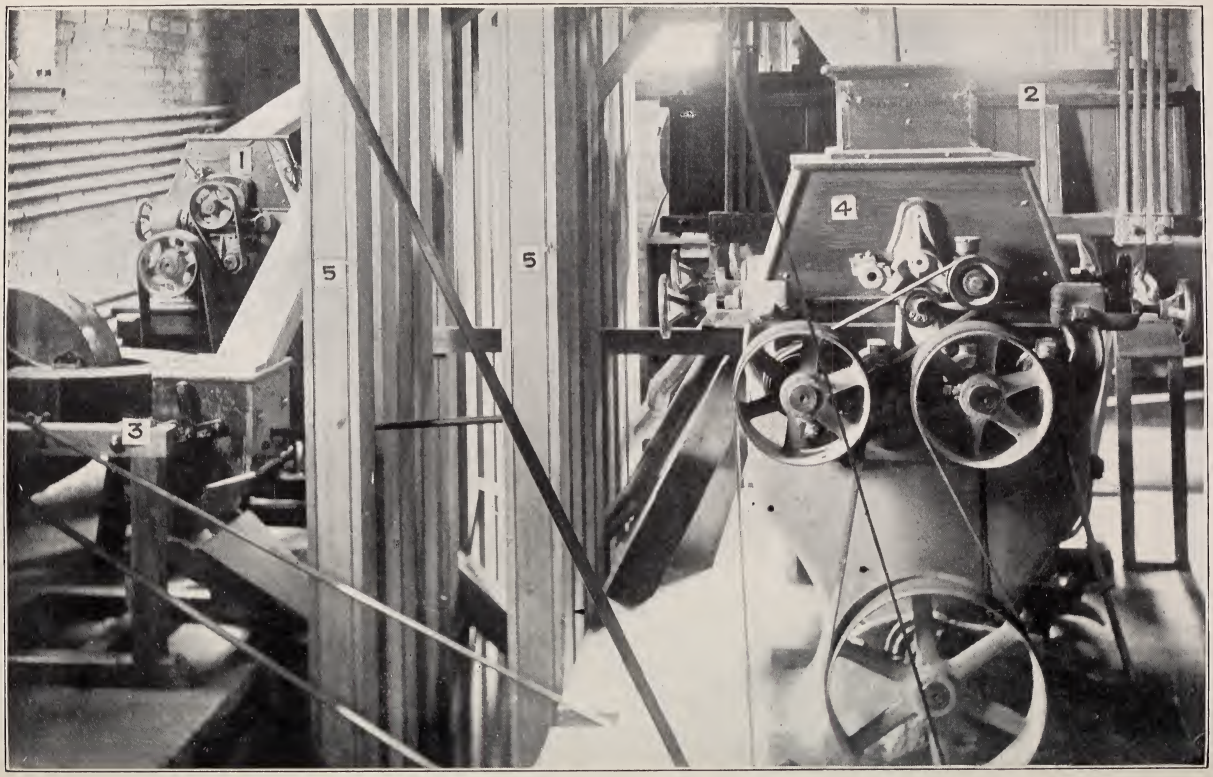
MILLING OF SAMPLES.

In the milling system employed the cleaned wheat is passed along to the first break, where it receives its first reduction. The "chop" is carried to the sifter by means of an elevator and separated into break flour, middlings, coarse bran, and material for the second break, where similar streams are obtained. The middlings are reduced between smooth rollers, purified by the aspirator, bolted in the sifter, and the reduced and purified product recovered as middlings flour or patent flour. In the system of milling followed, two grades of middlings flour, i. e., first and second, a break flour, and a low-grade flour, are obtained. From 70 to 75 per cent of the wheat milled, depending upon its quality, is recovered as flour with this experimental mill, and from 25 to 30 per cent is returned as bran, shorts, and feed.

The general plan of the milling system is shown in the figure herewith (fig. 1).

The milling plant used consists of two stands with corrugated and smooth rollers. By passing the material over the rolls a second time a four-break system of milling is secured. The milling of durum wheat for the production of semolina requires a different granulation and bolting of the middlings from that used in the preparation of flour from ordinary hard wheats for bread-making purposes. The aim is to secure medium coarse granular middlings, i. e., semolina, rather than fine flour, and it follows that the proportion of wheat obtained as middlings, which would ordinarily be reground, is greater than in flour milling. Manufacturers state that for macaroni making semolina is required which will not pass through a No. 10 bolting cloth. In milling for bread-making purposes the flour must be fine enough to pass through a No. 10 or 11, and in some cases a No. 12 or 14 bolting cloth.

For the investigations reported herewith the Kubanka variety of



EXPERIMENTAL FLOUR MILL.

1, second break (the first break is not shown); 2, sifter; 3, aspirator for purifying middlings; 4, middlings reduction rolls; 5, elevators for conveying mill streams.

durum wheat was selected as this appears to be one of the best varieties both as regards yield and the quality of its milling products. In each series of experiments the wheat selected was sound, bright, clean, and free from weed seeds, that used in 1904 weighing about 60 pounds to the bushel and that in 1905 about 63 pounds. As in ordinary milling, the wheat was softened or tempered by the addition of water prior to grinding. This prevents the bran from breaking up into fine

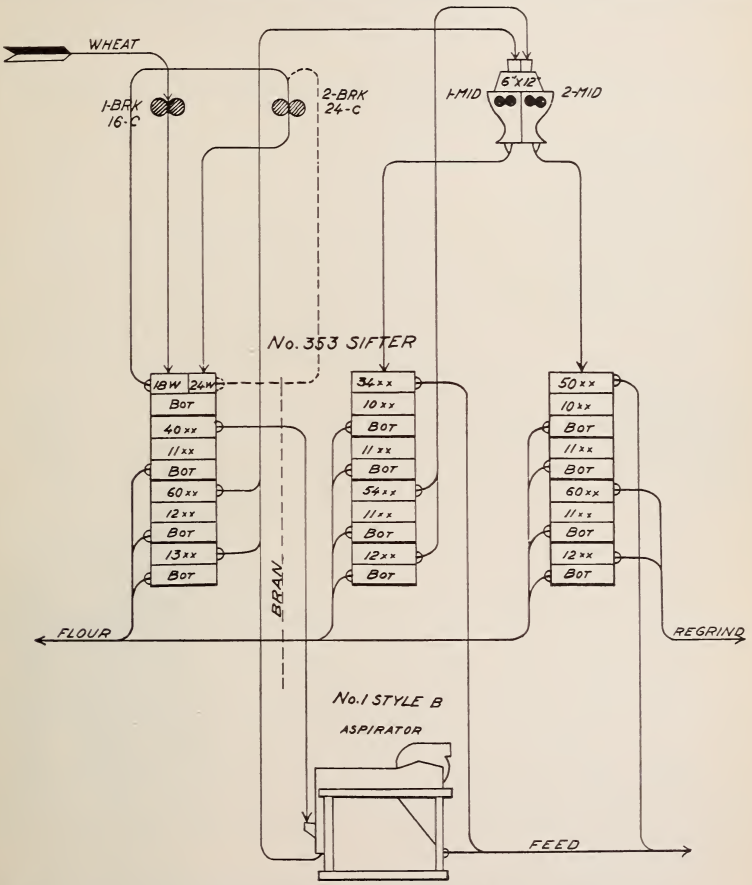


Fig. 1.—General plan of milling system.

pieces and contaminating the flour. Owing to the hard, flinty nature of the durum wheat a longer time and more water is required for tempering than with ordinary wheat flour. About a quart of water per 100 pounds of wheat was used, and the dampened grain was allowed to stand for twenty-four hours at a temperature of 20° C. before grinding.

The samples were milled under the supervision of Mr. Robert Dewar, an experienced miller, who at the time was engaged in special

work in wheat and flour testing at the Minnesota School of Agriculture. The amount ground in 1904 weighed 250 pounds, and that in the following year 172 pounds. It was noted that the electric current used for running the mill registered 28 to 35 amperes instead of 25 to 32 amperes, as in milling ordinary hard Kansas and Dakota wheats. The following table shows the kinds and amounts of milling products obtained from the two lots of wheat ground:

TABLE 42.—*Milling products obtained from durum wheat.*

Kind of product.	Amount obtained.	
Experiments made in 1904.	*Pounds.*	*Per cent.*
First middlings flour	33	13.2
Second middlings flour	32	12.8
Coarse middlings flour	78	31.2
Break flour	10	4.0
Flour recovered from tailings	15	6.0
Flour recovered from feed	5	2.0
Bran	21	8.4
Shorts and fine bran	38	15.2
Feed	7	2.8
Aspirator bran and dust	3	1.2
Elevator boots, flour and stock in	5	2.0
Loss	3	1.2
Total	250	100.0
Experiments made in 1905.		
First middlings flour	31.8	18.4
Second middlings flour	38.5	22.4
Coarse middlings flour	16.5	9.6
Break flour	7.5	4.4
Tailings flour	12.5	7.3
Bran	29.0	16.8
Shorts	33.5	19.5
Loss (dust)	2.7	1.6
Total	172.0	100.0

In the first milling test 71.2 per cent of the wheat as milled was recovered as flour; 26.4 per cent as bran, shorts, and feed, and 1.2 per cent as aspirator dust. The total material recovered was a little less than the amount used, the loss in grinding being 1.2 per cent. In the second test 62.1 per cent of the wheat used was recovered as middlings and flour of different grades, and 36.3 per cent as offals. The loss in milling was 1.6 per cent. The higher flour yield in 1904 was largely due to regrinding the tailings and offals. This resulted in lowering the commercial grade of the flour, and hence was omitted in 1905.

As noted above, in milling durum wheat the bran breaks readily and forms fine particles which find their way into the shorts, and so it happens that the relative amounts of bran and shorts are about the opposite of those found in milling ordinary wheat. In milling ordinary varieties of hard wheat by this same milling system 70 to 75 per cent of the grain is obtained as flour, including all grades. It will be seen, therefore, that there is little difference in the total yield of flour from durum and ordinary varieties of hard wheat, when the offals

from the durum wheat are remilled. A comparison of similar data for the two sorts shows the relative proportion of different grades of flour varies with the two types of wheat. Owing to the flinty character of the durum wheat there is a tendency for the stock to resist reduction and to find its way into the tailings. This results in an unequal division of the work of reduction among the various stands of rollers. When the coarse middlings and tailings are reground the final milling products obtained are about the same as with ordinary wheat.

COMPOSITION OF SAMPLES OF WHEAT AND MILLING PRODUCTS.

For purposes of comparison, samples of hard Scotch fife spring wheat, grown under the same conditions as the durum wheat, were milled.

The following table shows the composition of the durum wheats and the Scotch fife wheats selected for comparison, and their milling products, as well as of the macaroni made from the durum wheats:

TABLE 43.—*Composition of durum and hard spring wheats and their milling products.*

Sample No.	Kind of material.	Water.	Protein.	Fat.	Total carbohydrates.		Ash.
					Crude fiber.	Nitrogen-free extract.	
	Experiments made in 1904.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*
486	Durum wheat	8.76	12.37	2.07	74.92		1.88
	Durum wheat milling products:						
487	First middlings flour	10.85	11.69	1.47	75.20		.79
488	Second middlings flour	10.82	10.78	1.21	76.52		.67
489	Coarse middlings flour	10.72	11.75	1.52	75.29		.72
490	Break flour	11.32	12.36	2.10	72.92		1.30
495	Mixed flour (Nos. 487, 488, 489, 490)	10.77	11.64	1.27	75.56		.76
493	Shorts	11.62	14.05	3.42	68.59		2.32
494	Feed	10.00	12.37	3.22	72.47		1.94
491	Bran, coarse	11.86	12.82	4.21	65.86		5.25
492	Bran, fine	11.79	14.36	5.48	63.31		5.06
495A	Macaroni made from mixed flour No. 495	11.77	11.80	1.27	74.46		.70
496	Hard Scotch fife spring wheat	11.99	14.30	2.05	69.81		1.85
	Hard Scotch fife spring wheat milling products:						
497	First middlings flour	11.95	11.96	1.11	74.56		.42
498	Second middlings flour	10.84	11.89	1.28	75.54		.45
499	Break flour	11.51	13.54	1.42	73.00		.53
	Experiments made in 1905.						
600	Durum wheat	10.48	12.45	2.48	2.83	70.09	1.67
	Durum wheat milling products:						
601	First middlings flour	10.84	11.11	2.04	75.47		.54
602	Second middlings flour	9.91	11.95	2.24	75.36		.54
603	Coarse middlings flour	10.36	12.32	1.67	74.77		.88
604	Break flour	12.09	11.08	2.19	73.97		.67
605	Tailings flour	10.43	13.69	2.14	73.20		.54
606	Bran	11.77	13.28	5.39	9.09	56.67	3.85
607	Shorts and feed	11.10	12.99	7.93	8.64	56.79	2.55
582	Macaroni made from mixture of flours Nos. 601, 602, 603, 604	7.57	11.57	.89	79.06		.91
608	Hard Scotch fife spring wheat	11.91	12.09	2.16	2.58	69.19	2.07
	Hard Scotch fife spring wheat milling products:						
609	First middlings flour	11.15	10.60	1.11	76.66		.48
610	Second middlings flour	9.61	11.39	1.35	77.01		.64
611	Break flour	11.95	11.00	1.40	74.70		.95

As will be seen, the durum wheat used in 1904 contained 12.37 per cent of protein, while the hard Scotch fife wheat grown upon an adjoining field contained 14.30 per cent; the durum wheat used in 1905 contained 12.45 per cent and the hard Scotch fife wheat 12.09 per cent.

As is often the case, there is some difference in the appearance of the individual kernels of the durum wheat, and in connection with some work carried on at the Minnesota Experiment Station[a] the amount of protein in kernels of various character was studied. An average sample of the durum wheat milled in 1904 contained 12.37 per cent protein. Selected, dark-colored, hard, glutinous kernels showed 12.76 per cent, and light-colored, soft, starchy kernels, 10.60 per cent. Medium perfect kernels contained 12.56 per cent and small but equally well-filled ones 11.19 per cent. In former investigations[b] it has been shown that as a general rule the proportion of protein in standard patent flour is only 0.6 to 0.7 per cent less than in the wheat from which it was milled. In the case of the durum wheat the mixed flour or semolina contained 0.73 per cent less protein than the whea or approximately the same proportion as in the case of average hard wheat. As shown by the analyses reported, the durum wheat flour ground in 1904 and the flour and other milling products made from it contained about the same percentage amounts of protein, fat, and carbohydrates as are found in an average bread wheat and its milling products.

In durum wheat flour No. 495 it was found that 48.9 per cent of the total nitrogen present was in the form of gliadin. In patent flours made from hard spring wheat the gliadin nitrogen constitutes 52 to 61 per cent of the total nitrogen.[c] In the milling test carried on in 1905 it was observed that the durum wheat and also the ordinary wheat grown in the same locality contained less protein than the wheats ground the preceding year, and in fact a smaller proportion of this constituent than is usually the case with the local hard wheats. This is due, it is believed, to unusual climatic conditions, i. e., excessive rainfall and low temperature which prevailed during the growing season of the wheats. Notwithstanding its low protein content, the durum wheat selected is believed to be typical of similar wheats grown the same season in that part of Dakota. The flour samples milled from the durum wheat show in general the same percentage composition as those milled from the ordinary hard spring wheat selected for purposes of comparison.

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[a] Minnesota Station Bul. 85, p. 186.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 10.

[c] Minnesota Station Bul. 85, p. 207.

MANUFACTURE OF THE MACARONI.

In both tests the semolina used for the manufacture of macaroni included all the flour and middlings except the dark-colored break flour. The mixture was somewhat more finely ground and a little darker in color than that used for the commercial grades of macaroni, but it was the object to use as much of the wheat kernel as possible without including the break flour and offals rather than to prepare a high-grade commercial article which would include only a part of the middlings.

The macaroni was made in the presence of the author, the process of manufacture being as follows: The semolina was first mixed with about 30 per cent of water and made into a stiff dough by means of a mixing machine such as is used for bread-making purposes in many bakeries. The dough was then kneaded in a second machine provided with heavy iron rollers and passed to a third machine, where it was rolled into long thin sheets and finally made into rolls a foot or so in diameter and about 3 feet long. These rolls were placed in cylindrical presses provided with a perforated plate in the bottom with a wire suspended in each opening, though not so as to completely close the perforation. The dough is pressed through these orifices, making long, hollow tubes about one-eighth inch in diameter. The macaroni as it comes from the machine is spread by hand on trays, is cut into the desired lengths, and placed in racks to dry in the curing room at a temperature of 70° F. From seven to ten days are required for the drying and curing of the macaroni and it is then packed and ready for use.

The water used in mixing the dough is practically all removed in drying the macaroni, and, in this investigation, the analysis of the dry macaroni showed that it contained about the same percentage of moisture as the original flour or semolina. The conditions under which the drying takes place would suggest that but little loss of dry matter due to fermentation is possible. Indeed, mechanical losses appear to be the main losses in the preparation of macaroni, and these are not large. The conditions under which this macaroni was made did not permit of careful weighing of the flour and the finished product with a view to studying the losses and changes during manufacture. In fact, a study of its nutritive value was the object sought rather than a technical chemical study of the preparation of macaroni.

In the first test the composition of the mixed flour used for macaroni making was recorded. As will be seen by referring to Table 43, this flour (No. 495) and the uncooked macaroni made from it (No. 495A) have practically the same composition. A microscopic examination of the macaroni suggested that there was a slight change in the form

and character of the starch granules due to the treatment received during the process of manufacture. The action of the water, the kneading, rolling, and drying influenced the physical character of the macaroni and possibly caused a slight hydration of the starch and proteids without materially affecting their percentage amounts.

COMPOSITION OF SAMPLES OF FOOD MATERIALS.

In connection with the digestion experiments samples of the food materials were analyzed in the usual way (see page 13). In the case of macaroni, samples of the raw material were analyzed. Composite samples of the bread were prepared for analysis in the way described on page 15. For each experimental period a composite sample of the milk or cream, which formed a part of the ration, was prepared by placing in a can each day quantities proportional to the total amounts consumed, potassium bichromate being used as a preservative. The following table shows the composition of the foods used in the digestion experiments:

TABLE 44.—*Composition of food materials used in digestion experiments with macaroni and durum wheat breakfast food.*

Sample No.	Kind of material.	Water.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
	Experiments made in 1904.						
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
501	Macaroni, cooked, air-dry	12.01	11.64	1.27	74.37	0.71	3.860
500	Durum wheat flour bread	36.50	8.18	.89	53.46	.97	2.813
516	.....do	32.70	8.67	.94	56.67	1.02	2.982
502	Milk, composite sample	86.20	3.25	4.87	4.90	.78	826
509	.....do	86.48	3.44	4.68	4.65	.75	834
	Experiments made in 1905.						
582	Macaroni, raw	7.57	11.57	.89	79.06	.91	4.160
587	Durum wheat breakfast food	11.35	11.14	2.12	73.85	1.54	4.020
593	Milk	87.18	2.98	4.12	4.92	.80	770
583	Cream	79.44	3.37	10.65	5.72	.82	1.680

COMPOSITION OF FECES AND URINE.

The urine and feces were collected for analysis in the usual way, the separation of the feces pertaining to each experimental period being secured by the use of lampblack taken in capsules.[a] A composite sample of urine was prepared for analyses by uniting aliquot samples of the quantities voided each day. A small amount of formalin was used to prevent fermentation, and the samples were kept in a cool place. Tables 45 and 46 show the composition of the dry matter of the feces and the amount, specific gravity, and nitrogen content of the urine in the digestion experiments.

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 143.

TABLE 45.—*Composition of dry matter of feces from digestion experiments with macaroni.*

Sample No.	Whence obtained.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
503	Experiment No. 493	29.52	16.45	29.92	24.11	4.879
504	Experiment No. 494	24.10	14.86	37.40	23.64	5.302
505	Experiment No. 495	27.22	10.42	41.49	20.87	4.269
513	Experiment No. 496	28.07	12.24	29.69	30.00	4.197
514	Experiment No. 497	23.94	10.06	39.07	26.93	5.106
515	Experiment No. 498	32.59	10.07	29.91	27.43	4.240
597	Experiment No. 592	29.76	9.46	30.34	30.44	4.159
598	Experiment No. 593	23.75	8.62	39.07	28.56	4.776
599	Experiment No. 594	28.97	13.47	33.03	24.53	4.993
588	Experiment No. 595	20.15	8.01	51.09	20.75	4.774
589	Experiment No. 596	16.92	8.52	58.90	15.66	4.969
590	Experiment No. 597	21.91	11.06	51.14	15.89	4.920

TABLE 46.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with macaroni.*

Sample No.	Subject No.	Whence obtained.	Total amount voided.	Specific gravity.	Nitrogen.
			Grams.		*Per cent.*
506	1	Experiment No. 493	5,506	1.027	1.28
507	2	Experiment No. 494	4,546	1.033	1.62
508	3	Experiment No. 495	5,230	1.025	1.13
510	1	Experiment No. 496	6,545	1.027	1.06
511	2	Experiment No. 497	6,655	1.031	1.20
512	3	Experiment No. 498	6,655	1.027	1.04
594	1	Experiment No. 592	1,619	1.024	1.04
595	2	Experiment No. 593	3,826	1.032	1.20
596	3	Experiment No. 594	4,722	1.029	1.25
584	1	Experiment No. 595	3,828	1.025	.86
585	2	Experiment No. 596	4,021	1.030	1.19
586	3	Experiment No. 597	5,482	1.022	.79

EXPERIMENTAL METHODS.

The general plan of these digestion experiments was the same as that for the comparison of the entire-wheat, graham, and straight-grade breads, described on page 18. All of the food consumed for a period of four days was weighed, sampled, and analyzed, as well as all the urine and feces pertaining to the experimental period.

In the calculation of the digestibility of the macaroni and durum wheat flour bread together, in the experiments made in 1904, and of the macaroni in those made in 1905, the milk which formed part of the ration was assumed to have the following digestibility: Protein, 97 per cent; fat, 95 per cent; carbohydrates, 98 per cent; energy available to the body, 95 per cent. These are the figures used in the digestion experiments with bread and milk already described in this bulletin.

The digestibility of the cereal alone in the experiments made with the breakfast food prepared from durum wheat was computed on the assumption that 97 per cent of the protein and 95 per cent of the fat of the cream eaten with it were digested.

DETAILS OF THE DIGESTION EXPERIMENTS.

In the first series of tests six experiments were made to determine the digestibility and nutritive value of the specially prepared macaroni. In order to give variety to the diet without using any considerable number of food materials, bread made from some of the flour used for the manufacture of the macaroni formed a part of the ration. This flour made bread of good quality, with a characteristic yellow tinge. The loaf was not quite as large or of so good quality as that made from a like amount of the hard wheat patent flours made from samples Nos. 497 and 498. The only food used in addition to cooked macaroni and bread made from durum wheat flour was milk. In the first three experiments about one-third more macaroni than bread (on the dry-matter basis) was used, while in the last three experiments the ration contained about two and a half times as much macaroni as bread. The subjects were healthy men engaged in moderately severe labor. In each case three subjects were used, and each experiment covered a period of four days.

The macaroni was prepared for the table by cooking in boiling water for twenty minutes, and a weighed quantity of the dried material was cooked separately for each subject. The water was drained off and a small amount of milk added. The macaroni was then warmed in an oven and served. Analyses were made of the waters drained from the cooked macaroni and it was found that they contained from 0.03 to 0.04 per cent of the total nitrogen originally present in the macaroni, as well as a somewhat larger amount of carbohydrates. In ordinary household practice the material removed would be lost, as the water in which the macaroni was cooked would be thrown away. The material lost constitutes about 2.25 per cent of the soluble material originally present in the macaroni, which is about the same quantity as is lost by the processes of fermentation followed in bread making.[a] It is natural to suppose that the quantity of water used would affect the amount of material dissolved from the macaroni, and it is obvious, therefore, that where strict economy is desired small rather than large amounts of water should be used. In calculating the results of the digestion experiments made in 1904 a correction was introduced for the proteids lost in cooking by deducting 0.03 per cent of nitrogen from the total amount present in the original material. With this correction it was found that the dry matter of the uncooked and the cooked macaroni had practically the same percentage composition. When compared on the basis of dry matter, little, if any, difference was observed between the composition of the durum flour, the cooked macaroni, and the durum-flour bread. In the experiments made in 1905, the quantities of nutrients supplied by the cooked

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 33.

macaroni were computed on the basis of the composition of the raw material, as the work of the previous year had shown that the composition of the air-dried, cooked, and raw macaroni was so similar that no appreciable error was introduced by this method.

In the second series, three digestion experiments were made with a ration limited to macaroni and milk. The subjects, healthy young men engaged in moderate muscular work, were not inconvenienced by the simple character of the diet and it is believed that the results obtained may be regarded as normal.

For purposes of comparison three digestion experiments were also made with a breakfast cereal made from durum wheat. During the processes of manufacture of this rolled-wheat preparation a part of the bran was removed. This breakfast food, cooked in water in the usual way, was palatable and in flavor very much like similar breakfast foods prepared from ordinary wheat. It was eaten with cream, these two articles constituting the entire ration.

The details of the separate digestion experiments and the income and outgo of nitrogen are given in Tables 47 to 52.

EXPERIMENTS WITH MACARONI AND DURUM WHEAT BREAD.

DIGESTION EXPERIMENT NO. 493.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 1, 24 years of age, employed at farm labor.

Weight.—At the beginning of the experiment 173.5 pounds; at the close 173.25 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 11, 1904.

TABLE 47.—*Results of digestion experiment No. 493.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	900.0	104.8	11.4	669.3	6.4	3,474
500	Bread	965.0	78.9	8.6	515.9	9.3	2,715
502	Milk	7,050.0	229.1	343.4	345.5	55.0	5,823
	Total		412.8	363.4	1,530.7	70.7	12,012
503	Feces (water-free)	86.0	25.4	14.2	25.7	20.7	420
	Estimated feces from milk		6.9	17.2	6.9		247
	Estimated feces from macaroni and bread		18.5		18.8		173
	Total amount digested		387.4	349.2	1,505.0	50.0	11,592
	Estimated digestible nutrients in macaroni and bread		165.2		1,166.4		6,016
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		93.9	96.1	98.3	70.7	(96.5)
	Estimated coefficients of digestibilty of macaroni and bread		89.8		98.4		(97.2)
	Proportion of energy actually available to the body:						
	In total food						92.5
	In macaroni and bread						93.9

During this experiment the subject eliminated 5,506 grams urine, containing 70.48 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 16.51 grams; outgo in urine 17.62 grams; and in feces 1.02 grams; implying a loss of 2.13 grams nitrogen, corresponding to 13.3 grams protein.

DIGESTION EXPERIMENT NO. 494.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 2, 21 years of age, employed at farm labor.

Weight.—At the beginning of the experiment 178.5 pounds; at the close 179 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 11, 1904.

TABLE 48.—*Results of digestion experiment No. 494.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	1,300.0	151.3	16.5	966.8	9.3	5,018
500	Bread	1,280.0	104.7	11.4	684.3	12.4	3,601
502	Milk	8,615.0	280.0	419.6	422.1	67.2	7,116
	Total	.....	536.0	447.5	2,073.2	88.9	15,735
504	Feces (water-free)	144.0	34.7	21.4	53.8	34.1	764
	Estimated feces from milk	.....	8.4	21.0	8.4	.....	337
	Estimated feces from macaroni and bread	.....	26.3	.....	45.4	.....	427
	Total amount digested	.....	501.3	426.1	2,019.4	54.8	14,971
	Estimated digestible nutrients in macaroni and bread	.....	229.7	.....	1,605.7	.....	8,192
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	93.5	95.2	97.4	61.7	(95.2)
	Estimated coefficients of digestibility of macaroni and bread	.....	89.7	.....	97.3	.....	(95.0)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	91.2
	In macaroni and bread	.....	.....	.....	.....	.....	91.7

During this experiment the subject eliminated 4,546 grams urine, containing 73.65 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 21.44 grams; outgo in urine 18.41 grams; and in feces 1.39 grams; implying a gain of 1.64 grams nitrogen, corresponding to 10.3 grams protein.

DIGESTION EXPERIMENT NO. 495.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 3, 25 years of age, employed at janitor work.

Weight.—At the beginning of the experiment 140.5 pounds; at the close 140.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 11, 1904.

TABLE 49.—*Results of digestion experiment No. 495.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	1,250.0	145.5	15.9	929.6	8.9	4,825
500	Bread	1,283.0	104.9	11.4	685.9	12.5	3,609
502	Milk	6,325.0	205.6	308.0	309.9	49.3	5,224
	Total	.....	456.0	335.3	1,925.4	70.7	13,658
505	Feces (water-free)	149.0	40.6	15.5	61.8	31.1	636
	Estimated feces from milk	.....	6.2	15.4	6.2	.....	203
	Estimated feces from macaroni and bread	.....	34.4	.....	55.6	.....	433
	Total amount digested	.....	415.4	319.8	1,863.6	39.6	13,022
	Estimated digestible nutrients in macaroni and bread	.....	216.0	.....	1,559.9	.....	8,001
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	91.1	95.4	96.8	56.0	(95.3)
	Estimated coefficients of digestibility of macaroni and bread	.....	86.3	.....	96.6	.....	(94.9)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	91.5
	In macaroni and bread	.....	.....	.....	.....	.....	91.7

During this experiment the subject eliminated 5,230 grams urine, containing 59.10 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 18.24 grams; outgo in urine 14.78 grams; and in feces 1.62 grams; implying a gain of 1.84 grams nitrogen, corresponding to 11.5 grams protein.

DIGESTION EXPERIMENT NO. 496.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 1. Conditions as in experiment No. 493.

Weight.—At the beginning of the experiment 173.25 pounds; at the close 174 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 15, 1904.

TABLE 50.—*Results of digestion experiment No. 496.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	1,275.0	148.4	16.2	948.2	9.0	4,921
516	Bread	630.0	54.6	5.9	357.0	6.4	1,879
509	Milk	8,875.0	305.3	415.4	412.7	66.6	7,402
	Total	.....	508.3	437.5	1,717.9	82.0	14,202
515	Feces (water-free)	123.0	34.5	15.1	36.5	36.9	516
	Estimated feces from milk	.....	9.2	20.8	8.3	.....	293
	Estimated feces from macaroni and bread	.....	25.3	.....	28.2	.....	223
	Total amount digested	.....	473.8	422.4	1,681.4	45.1	13,686
	Estimated digestible nutrients in macaroni and bread	.....	177.7	.....	1,277.0	.....	6,577

TABLE 50.—*Results of digestion experiment No. 496*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 93.2	*Per cent.* 96.6	*Per cent.* 97.9	*Per cent.* 55.0	*Per cent.* (96.4)
	Estimated coefficients of digestibility of macaroni and bread		87.5		97.8		(96.7)
	Proportion of energy actually available to the body:						
	In total food						92.2
	In macaroni and bread						93.5

During this experiment the subject eliminated 6,545 grams urine, containing 69.38 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 20.33 grams; outgo in urine 17.35 grams; and in feces 1.38 grams; implying a gain of 1.60 grams nitrogen, corresponding to 10 grams protein.

DIGESTION EXPERIMENT NO. 497.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 2. Conditions as in experiment No. 494.

Weight.—At the beginning of the experiment 179 pounds; at the close 177.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 15, 1904.

TABLE 51.—*Results of digestion experiment No 497.*

Sample. No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	1,575.0	183.3	20.0	1,171.4	11.2	6,080
516	Bread	816.0	70.7	7.7	462.4	8.3	2,433
509	Milk	9,275.0	319.1	434.1	431.3	69.5	7,735
	Total		573.1	461.8	2,065.1	89.0	16,248
514	Feces (water-free)	132.0	31.6	13.3	51.6	35.5	674
	Estimated feces from milk		9.6	21.7	8.6		376
	Estimated feces from macaroni and bread		22.0		43.0		298
	Total amount digested		541.5	448.5	2,013.5	53.5	15,574
	Estimated digestible nutrients in macaroni and bread		232.0		1,590.8		8,215
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		94.5	97.1	97.5	60.1	(95.9)
	Estimated coefficients of digestibility of macaroni and bread		91.3		97.4		(96.5)
	Proportion of energy actually available to the body:						
	In total food						91.7
	In macaroni and bread						93.1

During this experiment the subject eliminated 6,655 grams urine, containing 79.86 grams nitrogen. The average nitrogen balance per day

was therefore as follows: Income in food 22.93 grams; outgo in urine 19.97 grams; and in feces 1.26 grams; implying a gain of 1.70 grams nitrogen, corresponding to 10.6 grams protein.

DIGESTION EXPERIMENT NO. 498.

Kind of food.—Milk, macaroni, and bread made from durum flour.

Subject.—Man No. 3. Conditions as in experiment No. 495.

Weight.—At the beginning of the experiment 140.5 pounds; at the close 138.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast June 15, 1904.

TABLE 52.—*Results of digestion experiment No. 498.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
501	Macaroni	1,305.0	151.9	16.6	970.5	9.3	5,037
516	Bread	657.0	57.0	6.2	372.3	6.7	1,959
509	Milk	6,225.0	214.1	291.3	289.5	46.7	5,192
	Total	.....	423.0	314.1	1,632.3	62.7	12,188
515	Feces (water-free)	124.0	40.4	12.5	37.1	34.0	526
	Estimated feces from milk	.....	6.4	14.6	5.8	.....	204
	Estimated feces from macaroni and bread	.....	34.0	.....	31.3	.....	322
	Total amount digested	.....	382.6	301.6	1,595.2	28.7	11,662
	Estimated digestible nutrients in macaroni and bread	.....	174.9	.....	1,311.5	.....	6,674
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	90.5	96.0	97.7	45.7	(95.7)
	Estimated coefficients of digestibility of macaroni and bread	.....	83.7	.....	97.7	.....	(95.4)
	Proportion of energy actually available to the body:						
	In total food	.....	.....	.....	.....	.....	91.8
	In macaroni and bread	.....	.....	.....	.....	.....	92.3

During this experiment the subject eliminated 6,655 grams urine, containing 69.21 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 16.92 grams; outgo in urine 17.30 grams; and in feces 1.62 grams; implying a loss of 2 grams nitrogen, corresponding to 12.5 grams protein.

EXPERIMENTS WITH MACARONI.

DIGESTION EXPERIMENT NO. 592.

Kind of food.—Macaroni and milk.

Subject.—Man No. 1. College student 27 years old, engaged part of the time at light work.

Weight.—At the beginning of the experiment 150 pounds; at the close 150½ pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 21, 1905.

TABLE 53.—*Results of digestion experiment No. 592.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
593	Milk	4,070	121.29	167.68	200.24	32.56	3,133.9
582	Macaroni	1,225	141.73	10.90	968.49	11.15	5,096.0
	Total	5,295	263.02	178.58	1,168.73	43.71	8,229.9
597	Feces (water-free)	98	29.16	9.27	29.73	29.83	407.6
	Estimated feces from milk		3.64	8.38	4.00		123.5
	Estimated feces from macaroni		25.52		25.73		284.1
	Total amount digested		233.86	169.31	1,139.00	13.88	7,822.3
	Estimated digestible nutrients from macaroni		116.21		942.76		4,811.9
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		88.91	94.81	97.46		(95.05)
	Estimated coefficients of digestibility of macaroni		81.99		97.34		(94.42)
	Proportion of energy available to body:						
	In total food						91.49
	In macaroni alone						91.57

During this experiment the subject eliminated 1,619 grams urine, containing 16.84 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 10.58 grams; outgo in urine 4.21 grams; and in feces 1.17 grams; implying a gain of 5.20 grams nitrogen, corresponding to 32.50 grams protein.

DIGESTION EXPERIMENT NO. 593.

Kind of food.—Macaroni and milk.

Subject.—Man No. 2. Student 22 years old, engaged three hours per day at manual labor.

Weight.—At the beginning of the experiment 183 pounds; at the close 182 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 21, 1905.

TABLE 54.—*Results of digestion experiment No. 593.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
593	Milk	5,050	150.49	208.06	248.46	40.40	3,888.5
582	Macaroni	1,500	173.55	13.35	1,185.90	13.65	6,240.0
	Total	6,550	324.04	221.41	1,434.36	54.05	10,128.5
598	Feces (water-free)	100	23.75	8.62	39.07	28.56	477.6
	Estimated feces from milk		4.51	10.40	4.97		178.6
	Estimated feces from macaroni		19.24		34.10		299.0
	Total amount digested		300.29	212.79	1,395.29		9,650.9
	Estimated digestible nutrients from macaroni		154.31		1,151.80		5,941.0

TABLE 54.—*Results of digestion experiment No. 593*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 92.67	*Per cent.* 96.11	*Per cent.* 97.28	*Per cent.*	*Per cent.* (95.28)
	Estimated coefficients of digestibility of macaroni		88.91		97.12		(95.21)
	Proportion of energy available to body:						
	In total food						91.28
	In macaroni alone						91.73

During this experiment the subject eliminated 3,826 grams urine, containing 45.91 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 12.96 grams; outgo in urine 11.48 grams; and in feces 0.95 gram; implying a daily gain of 0.53 gram nitrogen, corresponding to 3.31 grams protein.

DIGESTION EXPERIMENT NO. 594.

Kind of food.—Macaroni and milk.

Subject.—Man No. 3. College student 23 years old, with exercise equivalent to two hours per day of light work.

Weight.—At the beginning of the experiment 182 pounds; at the close 180 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 21, 1905.

TABLE 55.—*Results of digestion experiment No. 594.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
593	Milk	4,850	144.53	199.82	238.62	38.80	3,734.5
582	Macaroni	1,375	159.09	12.24	1,087.08	12.51	5,720.0
	Total	6,225	303.62	212.06	1,325.70	51.31	9,454.5
599	Feces (water-free)	114	33.02	15.35	37.65	27.96	569.2
	Estimated feces from milk		4.34	9.99	4.77		158.3
	Estimated feces from macaroni		28.68	5.36	32.88		410.9
	Total amount digested		270.60	196.71	1,288.05	23.35	8,885.3
	Estimated digestible nutrients from macaroni		130.41	6.88	1,054.20		5,309.1
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		89.12	92.76	97.16		(93.98)
	Estimated coefficients of digestibility of macaroni		81.97	56.21	96.97		(92.82)
	Proportion of energy available to body:						
	In total food						89.97
	In macaroni alone						89.34

During this experiment the subject eliminated 4,722 grams urine, containing 59.03 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 12.15 grams; outgo in urine 14.76 grams; and in feces 1.32 grams; implying a daily loss of 3.93 grams nitrogen, corresponding to 24.56 grams protein.

EXPERIMENTS WITH DURUM WHEAT BREAKFAST FOOD.

DIGESTION EXPERIMENT NO. 595.

Kind of food.—Durum wheat breakfast food and cream.

Subject.—Man No. 1. College student 27 years old, engaged part of the time at light work.

Weight.—At the beginning of the experiment 153 pounds; at the close 152 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 17, 1905.

TABLE 56.—*Results of digestion experiment No. 595.*

Sample No.		Weight of material.	Protien (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
583	Cream	1,720	57.96	183.18	98.38	14.10	2,889.6
587	Durum wheat breakfast food	1,075	119.76	22.79	793.89	16.56	4,321.5
	Total	2,795	177.72	205.97	892.27	30.66	7,211.1
588	Feces (water-free)	182	36.67	14.58	92.98	37.77	868.9
	Estimated feces from cream	.....	1.74	9.16	1.97	.....	121.6
	Estimated feces from durum wheat breakfast food	.....	34.93	5.42	91.01	.....	747.3
	Total amount digested	.....	141.05	191.39	799.29	.....	6,342.2
	Estimated digestible nutrients from durum wheat breakfast food	.....	84.83	17.37	702.88	.....	3,574.2
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	79.37	92.92	89.58	.....	(87.95)
	Estimated coefficients of digestibility of durum wheat breakfast food	.....	70.83	76.22	88.54	.....	(82.77)
	Proportion of energy available to body:						
	In total food	.....	.....	.....	.....	.....	85.56
	In durum wheat breakfast food alone	.....	.....	.....	.....	.....	80.25

During this experiment the subject eliminated 3,828 grams urine, containing 32.92 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 7.11 grams; outgo in urine 8.23 grams; and in feces 1.47 grams; implying a daily loss of 2.59 grams nitrogen, corresponding to 16.19 grams protein.

DIGESTION EXPERIMENT NO. 596.

Kind of food.—Durum wheat breakfast food and cream.

Subject.—Man No. 2. Student 22 years old, engaged three hours per day at manual labor.

Weight.—At the beginning of the experiment 182 pounds; at the close 181 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 14, 1905.

TABLE 57.—*Results of digestion experiment No. 596.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
583	Cream	2,240	75.49	238.56	128.13	18.37	3,763.2
587	Durum wheat breakfast food	1,400	155.96	29.68	1,033.90	21.56	5,628.0
	Total	3,640	231.45	268.24	1,162.03	39.93	9,391.2
589	Feces (water-free)	234	39.59	19.94	137.83	36.64	1,162.7
	Estimated feces from cream	.....	2.26	11.93	2.56	.....	157.4
	Estimated feces from durum wheat breakfast food	.....	37.33	8.01	135.27	.....	1,005.3
	Total amount digested	.....	191.86	248.30	1,024.20	.....	8,228.5
	Estimated digestible nutrients from durum wheat breakfast food	.....	118.63	21.67	898.63	.....	4,622.7
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	.....	82.89	92.56	88.14	.....	(87.62)
	Estimated coefficients of digestibility of durum wheat breakfast food	.....	76.06	73.01	86.92	.....	(82.14)
	Proportion of energy available to body:						
	In total food	.....	.....	.....	.....	.....	85.07
	In durum wheat breakfast food alone	.....	.....	.....	.....	.....	79.50

During this experiment the subject eliminated 4,021 grams urine, containing 47.85 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 9.26 grams; outgo in urine 11.96 grams; and in feces 1.58 grams; implying a daily loss of 4.28 grams nitrogen, corresponding to 26.75 grams protein.

DIGESTION EXPERIMENT NO. 597.

Kind of food.—Durum wheat breakfast food and cream.

Subject.—Man No. 3. College student 23 years old, with exercise equivalent to two hours per day of light work.

Weight.—At the beginning of the experiment 184 pounds; at close 182 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast February 14, 1905.

TABLE 58.—*Results of digestion experiment No. 597.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
583	Cream	2,720	91.66	289.68	155.58	22.30	4,569.6
587	Durum wheat breakfast food	1,700	189.38	36.04	1,255.45	26.18	6,834.0
	Total	4,420	281.04	325.72	1,411.03	48.48	11,403.6
590	Feces (water-free)	253	55.43	27.98	129.38	40.20	1,244.8
	Estimated feces from cream	.....	2.75	14.48	3.11	.....	180.7
	Estimated feces from durum wheat breakfast food	.....	52.68	13.50	126.27	.....	1,064.1
	Total amount digested	.....	225.61	297.74	1,281.65	.....	10,158.8
	Estimated digestible nutrients from durum wheat breakfast food alone	.....	136.70	22.54	1,129.18	.....	5,769.9

TABLE 58.—*Results of digestion experiment No. 597*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
	Coefficients of digestibility of total food		*Per cent.* 80.28	*Per cent.* 91.41	*Per cent.* 90.83	*Per cent.*	*Per cent.* (89.08)
	Estimated coefficients of digestibility of durum wheat breakfast food		72.18	62.54	89.94		(84.43)
	Proportion of energy available to body:						
	In total food						86.61
	In durum wheat breakfast food alone						81.93

During this experiment the subject eliminated 5,482 grams urine, containing 43.31 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 11.24 grams; outgo in urine 10.83 grams; and in feces 2.22 grams; implying a daily loss of 1.81 grams nitrogen, corresponding to 11.31 grams protein.

SUMMARY OF DIGESTION EXPERIMENTS WITH MACARONI AND DURUM WHEAT BREAKFAST FOOD.

The table below summarizes the results of the digestion experiments which were made with a ration of macaroni with durum wheat flour bread and milk, macaroni with milk, and durum wheat breakfast food with cream. For purposes of comparison the average results obtained in 21 experiments previously reported,[a] with a diet of patent wheat flour bread and milk, are also included.

TABLE 59.—*Digestibility of nutrients and availability of energy of entire rations containing macaroni and durum wheat flour products.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
493	1	Macaroni and durum wheat flour bread 1:1 with milk	*Per cent.* 93.9	*Per cent.* 96.1	*Per cent.* 98.3	*Per cent.* 92.5
494	2	.....do	93.5	95.2	97.4	91.2
495	3	.....do	91.1	95.4	96.8	91.5
		Average of 3 experiments	92.8	95.6	97.5	91.7
496	1	Macaroni and durum wheat flour bread 2:1 with milk	93.2	96.6	97.9	92.2
497	2	.....do	94.5	97.1	97.5	91.7
498	3	.....do	90.5	96.0	97.7	91.8
		Average of 3 experiments	92.7	96.6	97.7	91.9
		Average of above 6 experiments	92.8	96.1	97.6	91.8
592	1	Macaroni with milk	88.9	.....	97.5	91.5
593	2	.....do	92.7	.....	97.3	91.3
594	3	.....do	89.1	.....	97.2	90.0
		Average of 3 experiments	90.2	.....	97.3	90.9
		Average of all above experiments	91.9	96.1	97.5	91.5
595	1	Durum wheat breakfast food with cream	79.4	.....	89.6	85.1
596	2	.....do	82.9	.....	88.1	84.5
597	3	.....do	80.3	.....	90.8	86.6
		Average of 3 experiments	80.9	.....	89.5	85.4
		Patent flour bread with milk, average of 21 experiments	93.3	95.6	98.1	92.3

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 85, 101, 126, 143.

From Table 59 it will be seen that on an average 92.8 per cent of the protein of a ration of macaroni, bread made from durum wheat flour, and milk was digested and 91.8 per cent of the energy was available. As will be seen by reference to the table practically the same results were obtained when the ration contained large and small proportions of the bread made from durum wheat flour. With a ration of macaroni and milk the results obtained were very similar, 90.2 per cent of the protein being digestible and 90.9 per cent of the energy available. Considering the average values for all the rations containing macaroni, 91.9 per cent of the protein was digestible and 91.5 per cent of the energy available. The results obtained with a ration of durum wheat breakfast food and cream were lower, 80.9 per cent of the protein being digestible and 85.4 per cent of the energy available.

Table 60 shows the calculated digestibility of the macaroni and durum wheat flour products alone, and for purposes of comparison the calculated digestibility of patent flour bread when forming part of a ration of bread and milk. The methods of calculating these results and the factors used have been explained on page 63.

TABLE 60.—*Digestibility of nutrients and availability of energy of macaroni and durum wheat flour products.*

Experiment No.	Subject No.	Kind of food.	Protein.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*
493	1	Macaroni and durum wheat flour bread 1:1	89.8	98.4	93.9
494	2	.....do	89.7	97.3	91.7
495	3	.....do	86.3	96.6	91.7
		Average of 3 experiments	88.6	97.4	92.4
496	1	Macaroni and durum wheat flour bread 2:1	87.5	97.8	93.5
497	2	.....do	91.3	97.4	93.1
498	3	.....do	83.7	97.7	92.3
		Average of 3 experiments	87.5	97.6	93.0
		Average of above 6 experiments	88.1	97.5	92.7
592	1	Macaroni	82.0	97.3	91.6
593	2	.....do	88.9	97.1	91.7
594	3	.....do	82.0	97.0	89.3
		Average of 3 experiments	84.3	97.1	90.9
		Average of all above experiments	86.8	97.4	92.1
595	1	Durum wheat breakfast food	70.8	88.5	80.3
596	2	.....do	76.1	86.9	79.5
597	3	.....do	72.2	89.9	81.9
		Average of 3 experiments	73.0	88.4	80.6
		Patent flour bread, average of 21 experiments	88.1	97.8	92.0

On an average 88.1 per cent of the protein of macaroni and bread made from durum wheat flour was digested and 92.7 per cent of the energy was available. Considering the above average values and the range in the results of the individual tests, it will be seen that

the presence of large or small proportions of bread made from durum wheat flour had little effect on the digestibility of the total cereal food in the ration. This would indicate that the bread made from durum wheat flour had practically the same digestibility as the macaroni—that is, that it made little difference as regards digestibility whether the flour was made into a paste which was dried, boiled, and eaten or into a dough which was baked. In the tests in which macaroni was eaten without bread on an average 84.3 per cent of the protein was digested and 90.9 per cent of the energy available. Considering both range and average values, the figures obtained for macaroni alone agree quite closely with those obtained for macaroni plus durum wheat flour bread. When all the rations containing macaroni are taken into account it is found that on an average 86.8 per cent of the protein was digestible and 92.1 per cent of the energy available. Somewhat lower results were obtained with the durum wheat breakfast food than with the macaroni made from the same lot of wheat, the coefficient of the digestibility of protein being 73.0 per cent and the coefficient of availability of energy 80.6 per cent.

As will be seen by Table 60 the results obtained with macaroni differ little from the average values obtained with bread made from straight-grade flour.

As to the cost of nutrients of bread and macaroni, prices differ in different localities and at different times to such an extent that only general comparisons are possible. A pound of dry macaroni retailing for 10 cents contains approximately the same amount of nutrients as are present in 1.3 to 1.4 pounds of bread costing from 6 to 10 cents, the difference in nutritive value per pound of the two materials being due largely to a difference in water content. In other words, macaroni furnishes, pound for pound, somewhat more nutritive material than bread but at a higher cost. The use of macaroni in the diet is a matter which depends quite largely upon food habits and the relative cost of materials. In Italy, as is well known, this food is much more commonly used than in the United States. The results of dietary studies made in Chicago[a] confirms the belief that after immigration to this country the Italians retain in large measure their food habits, and macaroni is still a very important article of diet, replacing bread and other common cereal foods to a considerable extent. Macaroni and similar Italian pastes are favorite articles of diet in many American families. The experimental and other evidence available confirms the opinion that the Italian pastes are digestible and nutritious articles of diet, but that at ordinary prices bread is a somewhat cheaper source of nutrients. The use of macaroni is, however, desirable because of the variety which it introduces into the menu and the

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 55.

possibility it affords of making satisfactory combinations with other food materials.

As regards the use of durum wheat for making breakfast foods, the experiments reported herewith show that it is possible to produce goods which in composition and digestibility compare favorably with whole-wheat flour. The superior digestibility of the macaroni and bread is probably due to the fact that the ground grain from which these products are made offers a better opportunity for the action of the digestive juices than the flaked kernels of the breakfast food.

THE RESULTS OF AMERICAN AND OTHER EXPERIMENTS WITH MACARONI.

As noted on another page (p. 55), Rubner, Jacoangeli and Bonanni, and Cappelletti have studied the digestibility of macaroni and similar products, and it is interesting to compare the results of their experiments with those obtained in the investigations carried on at the Minnesota Experiment Station. The earliest of these experiments are those made by Rubner with a healthy man who lived exclusively on the materials studied. In the macaroni tests these were macaroni noodles made with and without the addition of wheat gluten. In one of the tests "Spaetzels," a sort of flour paste poured through a sieve into boiling water and quickly cooked, constituted the entire ration. When cooked this material seems comparable with macaroni or similar foods, though of course it is unlike them as regards method of preparation.

In connection with an investigation of the value of Indian corn, alone or with wheat, for making alimentary pastes, Jacoangeli and Bonanni studied the digestibility of macaroni made from wheat, as well as that of pastes from corn and corn and wheat, and also of corn-meal mush, such as is commonly eaten in Italy, i. e., polenta. The subject of the experiments was a healthy man. In the test with macaroni and other pastes these foods constituted the entire diet, being eaten in the form of soup. In all the tests two meals were taken each day, one at 10 o'clock in the morning and the other at 4 o'clock in the afternoon. So far as can be learned, the studies of the value of Indian corn for use in the manufacture of alimentary pastes, though undertaken upon a comparatively large scale, never passed the experimental stage.

Using three men as subjects, Cappelletti studied the digestibility of macaroni or a similar Italian paste, rice and "sitos," a sort of breakfast food made from a Sardinian variety of durum wheat by splitting the grain lengthwise and removing the outer layer. The foods were eaten in the form of thick soup.

The following table summarizes the results obtained by these investigators as well as the average results obtained at the Minnesota Experiment Station. In the case of the experiments cited for com-

parison, data regarding the coefficients of the availability of energy were not reported nor could these values be calculated from the experimental data included in the original publications.

TABLE 61.—*Summary of American and other experiments on the digestibility of macaroni.*

Kind of food.	Dry matter.	Protein.	Fat.	Carbohydrates.	Energy.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Macaroni noodles (Rubner)	95.7	82.9	94.3	99.8	.....
Macaroni noodles with wheat gluten (Rubner)	94.3	88.8	93.0	97.7	.....
Spaetzels (Rubner)	95.1	79.5	.....	98.4	.....
Macaroni made from best quality wheat flour (Jacoangeli and Bonanni)	96.1	91.2	87.6	97.5	.....
Macaroni made from low-grade flour (Jacoangeli and Bonanni)	94.8	90.8	86.2	96.3	.....
Macaroni (Cappelletti)	.....	86.9	87.9	97.4	.....
Durum wheat breakfast food (Cappelletti)	.....	78.7	92.0	96.1	.....
Macaroni with durum wheat flour bread (Snyder)	.....	88.1	.....	97.5	92.7
Macaroni (Snyder)	.....	84.3	.....	97.1	90.9
Durum wheat breakfast food (Snyder)	.....	73.0	.....	88.4	80.6

It will be seen from the figures in the above table that the results obtained with macaroni in the experiments at the Minnesota Experiment Station agree quite closely with those obtained by the European investigators quoted. In other words, the American-grown durum wheat produced macaroni which was equal in this respect to that made from European wheats. When it is remembered that the American macaroni is of excellent quality, and in appearance, flavor, and composition very like the standard European products, the conclusion seems warranted that in all important respects the American material is equal to the European. As previously noted, the breakfast food tested at the Minnesota Experiment Station had somewhat lower coefficients of digestibility than the macaroni made from the same lot of wheat, and it is interesting to note that Cappelletti also found that the durum wheat breakfast food contained somewhat lower proportions of digestible nutrients than the macaroni. The published data at present available regarding the average coefficients of breakfast foods from ordinary varieties of wheat are too limited for satisfactory comparisons, but it seems probable that durum wheat breakfast foods compare favorably with other wheats in this respect.

INCOME AND OUTGO OF NITROGEN.

In connection with the digestion experiments with macaroni and durum wheat breakfast food the income and outgo of nitrogen was determined. The data of this character for the individual experiments is summarized in Table 62:

TABLE 62.—*Average daily income and outgo of nitrogen in digestion experiments Nos. 493–498, 592–597.*

Experiment No.	Subject No.	Kind of food.	Nitrogen.			
			In food.	In urine.	In feces.	Gain (+) or loss (−).
493	1	Macaroni and durum wheat flour bread 1:1 with milk	*Grams.* 16.51	*Grams.* 17.62	*Grams.* 1.02	*Grams.* −2.13
494	2	do	21.44	18.41	1.39	+1.64
495	3	do	18.24	14.78	1.62	+1.84
496	1	Macaroni and durum wheat flour bread 2:1 with milk	20.33	17.35	1.38	+1.60
497	2	do	22.93	19.97	1.26	+1.70
498	3	do	16.92	17.30	1.62	−2.00
592	1	Macaroni with milk	42.33	16.84	4.67	+5.21
593	2	do	51.85	45.91	3.80	+ .54
594	3	do	48.58	59.03	5.28	−3.93
595	1	Durum wheat breakfast food with cream	28.43	32.92	5.87	−2.59
596	2	do	37.03	47.85	6.33	−4.29
597	3	do	44.95	43.31	8.88	−1.81

In six of the experiments there was an average daily gain of nitrogen and in an equal number there was a loss. As was noted in the discussion of data regarding the income and outgo of nitrogen in experiments with different sorts of bread reported earlier in this bulletin (p. 52), it is probable that in every case nitrogen equilibrium would have been reached if the experimental periods had been longer. On an average the proportion of nitrogen excreted in the feces was greater with the durum wheat breakfast food, i. e., with the coarser product, than with the macaroni, as might be inferred from the somewhat lower digestibility of the breakfast cereal referred to in the discussion of the digestion experiments. In general, no differences in the nitrogen balance were observed which could be attributed to the durum wheat products consumed.

CONCLUSIONS OF EXPERIMENTS WITH MACARONI.

In these investigations two samples of durum wheat grown in North Dakota were milled with an experimental mill at the Minnesota Experiment Station and the product obtained was made into macaroni, which was used for digestion experiments with healthy young men engaged in a fair amount of muscular work as subjects. It was found that when the offals from the durum wheat were remilled the total yield of flour from durum wheat was approximately the same as from ordinary wheats, but that the different grades of flour were obtained in somewhat different proportions. The durum wheat was somewhat harder to reduce and required more power in milling than ordinary wheat. The manufacture of semolina from durum wheat requires somewhat different tempering, granulation, and bolting than are required in the manufacture of flour for bread-making purposes from ordinary wheat. In the manufacture of macaroni the semolina or coarse flour undergoes

both physical and chemical changes. Water is removed in drying the macaroni and the starch and gluten apparently undergo a slight hydration. When macaroni is cooked in water about 2.25 per cent of the soluble matters present are extracted, which suggests that as little water as possible should be used in cooking the macaroni when strict economy is desirable.

As shown by experiments with healthy men, macaroni has approximately the same digestibility and supplies about the same amount of nutrients, pound for pound on a dry-matter basis, as bread made from straight-grade flour. Consuming either large or small amounts of bread made from durum wheat flour with the macaroni exercised no appreciable effect upon the digestibility of the nutrients and the availability of the energy present.

Macaroni is a highly digestible and nutritious article of diet, corresponding in these respects quite closely to bread, though at ordinary prices it furnishes nutrients at a somewhat greater cost than bread; nevertheless, it may be fairly considered an economical article of diet. Macaroni may be readily combined with other food materials and thus may be used to give variety to the diet.

The durum wheat breakfast food resembled quite closely in composition the macaroni made from similar wheat. It was not quite as thoroughly digested, though its digestibility was fairly high as compared with many vegetable foods. The observed differences in digestibility of the breakfast food and the flour products are undoubtedly due to methods of manufacture, the flour products being rather finely ground and therefore in a condition favorable for the action of the digestive juices.

Taken as a whole the tests show that these American-made macaronies were directly comparable with standard-made goods of European manufacture.

The general summary of results and conclusions on the digestibility and nutritive value of bread is given on pages 53 and 54 of this bulletin.

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